ATLAS Upgrade Program at BNL

F. Lanni

Outline

- ATLAS Upgrade R&D plans and schedule
- BNL's roles in the ATLAS Upgrades
- Manpower and organization
- Conclusions: Future plans and strategies of the BNL group

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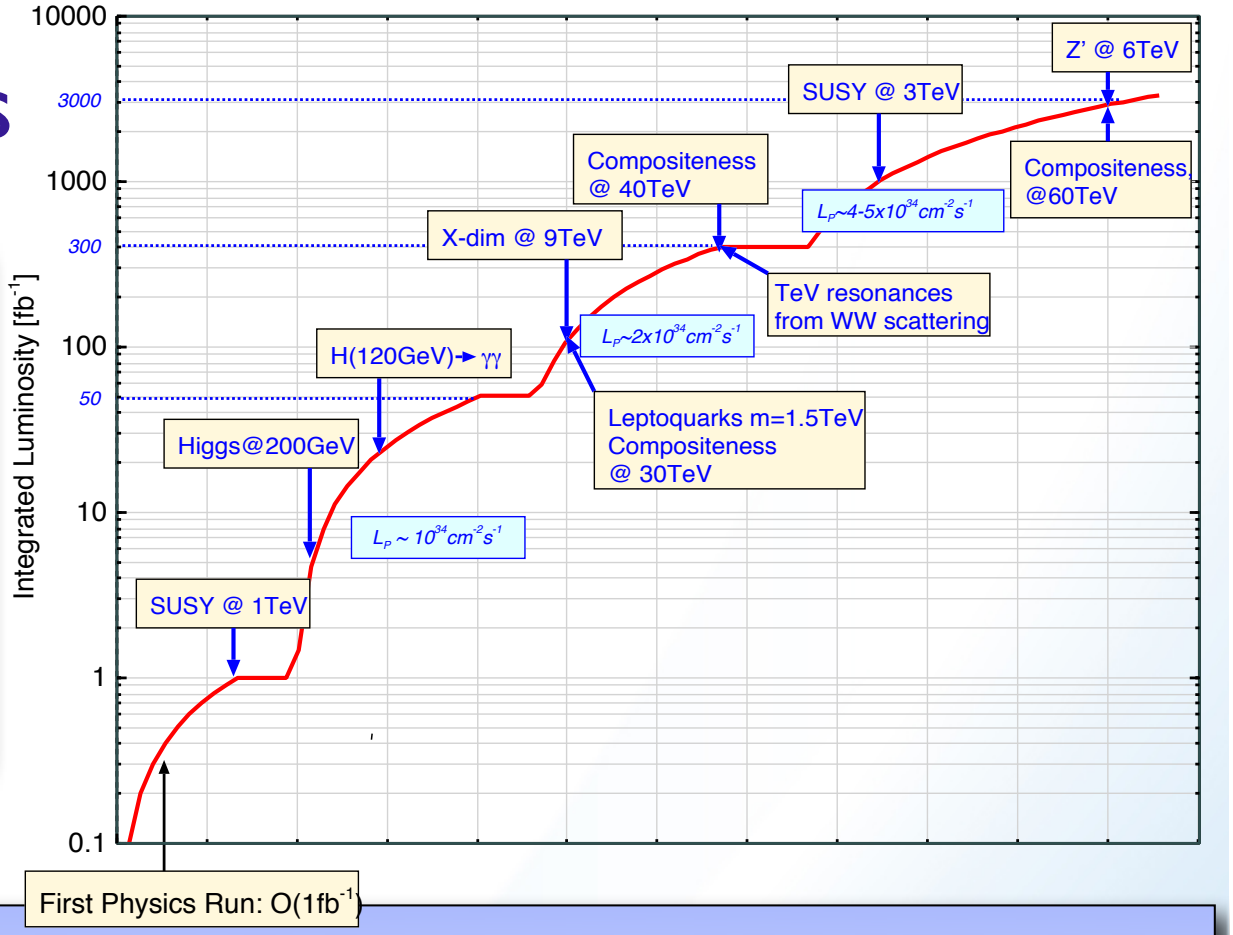
a passion for discovery
Office of Science U.S. DEPARTMENT OF ENERGY

ATLAS upgrades

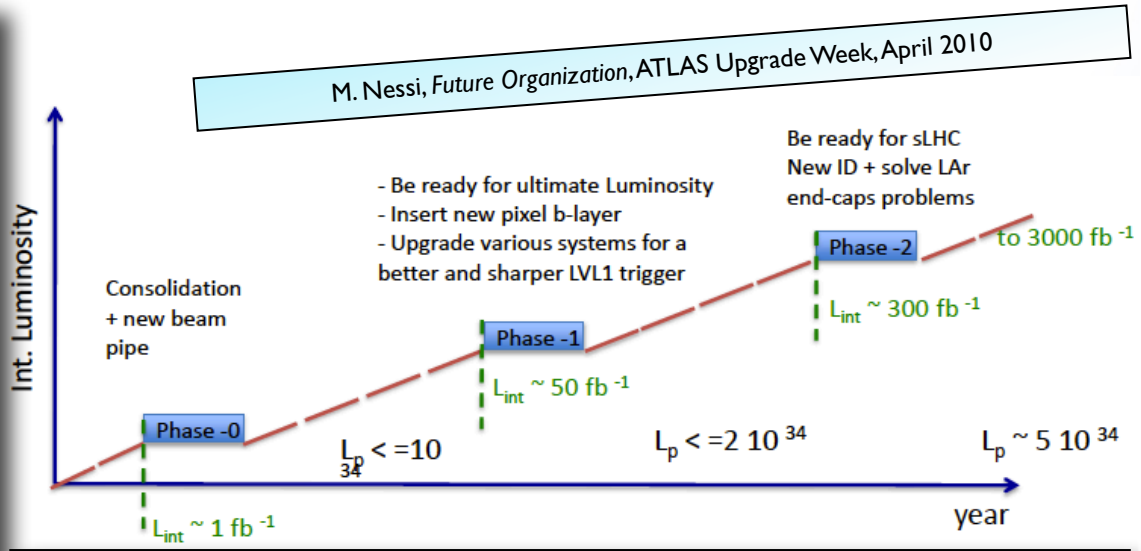
A strong and rich physics program for the next 10-20 years at the LHC will require ultimately an upgrade of the ATLAS detector



- ***Motivations for ATLAS upgrades other than radiation damage:***
  - ✓ Aging (some components >10yrs already)
  - ✓ Experience from commissioning and current running let us realize what and how we can make a better experiment
    - Technology advances allow for much more powerful tools not available at the time of original construction

ATLAS upgrades (2)

- ATLAS is revisiting upgrade strategy
  - ✓ Multi-phase plan for the next 10 years.
  - ✓ Fewer and longer shutdowns are preferred.
- ***Scenario with three long shutdowns interleaved by 3-4 years of full running***
  - ✓ **2012 (Phase-0):** 15 months defined by the LHC consolidation plan
  - ✓ **~2016-2017 (Phase-I):** 8-9 months
  - ✓ **~2020-2021 (Phase-II):** 18-20 months



- Currently ATLAS is evaluating how to optimize the deployment of each upgrade project in these 3 phases
- The plan will be be made when CERN sets the schedule with input from the four experiments and the accelerator
  - ✓ Expected planning update from CERN by the June Council meeting.

BNL Roles in the ATLAS Upgrades

- **BNL and the US community are an integral and influential part in ATLAS for the definition of strategies for upgrades through our participation in the ATLAS Upgrade Steering Group (USG):**
  - US members: A. Seiden (inner tracker), FL (calo.)
- **We map our plans on the ATLAS upgrade program starting from:**
  - ✓ Our strong role in the original construction, operations and performance studies of the current detector
  - ✓ Synergies with the local scientific and technical expertise (e.g. Instrumentation Division)...
  - ✓ ... and with our Generic Detector R&D program
- **... maintaining the expertise and the leadership roles in detector R&D for high intensity, high energy collider experiments.**

Phase-0

- Detector consolidation operations under M&O
- Tasks details at https://edms.cern.ch/document/1012396
  - ✓Consolidate infrastructure (cryogenics, UPS, access)
  - ✓Replace SS beampipe sections with Be/Al
  - ✓New Inner Detector external evaporative cooling plant
  - ✓Installation completion of few "extra-endcap" (EE) muon chambers and relative readout.
  - ✓Extra shielding
  - ✓Fix known problems (**Calo LVPS**, LAr OTx...)

BNL responsibility

LAr Low Voltage Power Supplies

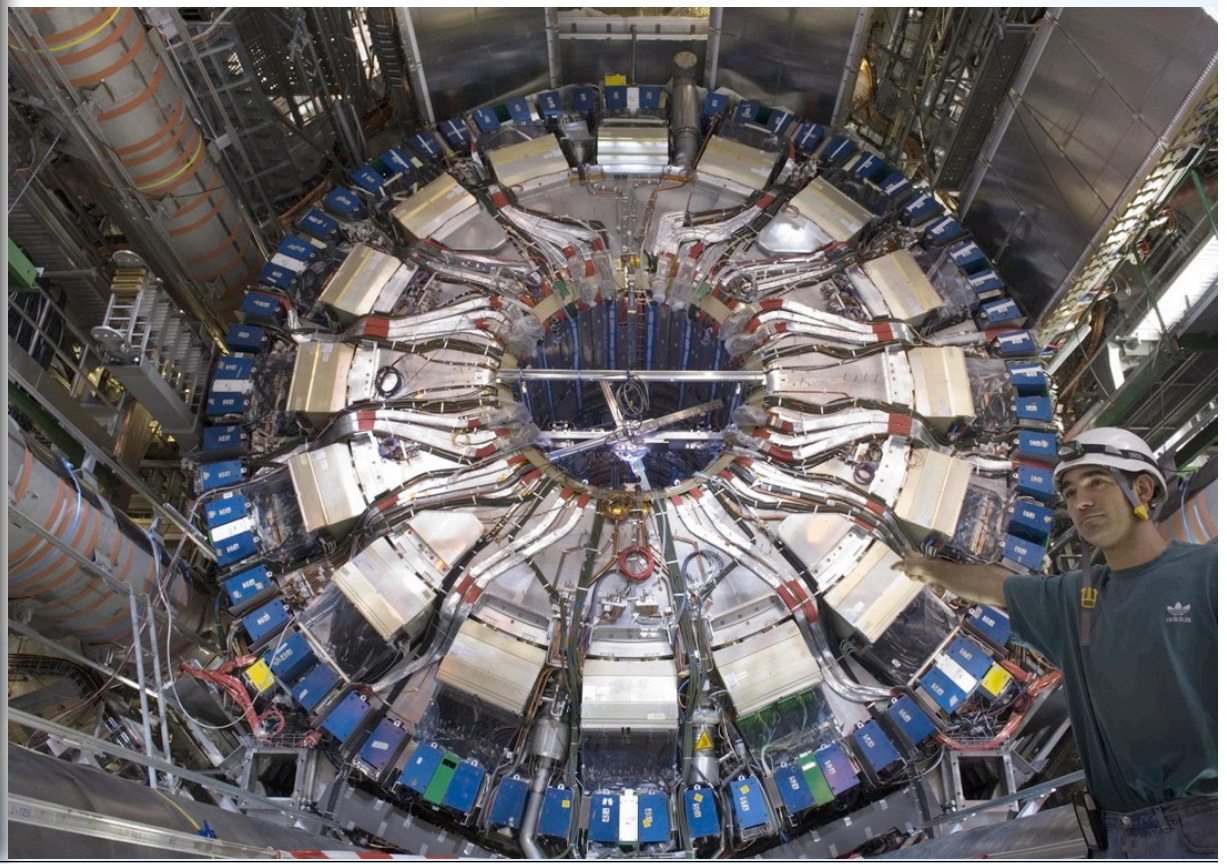
- 58 units on-detector
- Sourcing power to the Front-End electronics: ~150-170kW (~30% of ATLAS detector overall)
- Extensive activity in the last 3 years to consolidate the LVPS currently installed and develop a backup plan
- Development completed. Production starting now (68 units in total)

✓ Long-term burn-in (2-3 months) on each unit before installation on detector

A BNL deliverable:

- P. Bichoneau, H. Chen, D. Damazio, A. Hoffmann, J. Kierstead, F. Lanni, W. Louie, D. Makowiecki, W. Ng, S. Rescia, J. Sandberg, K. Sexton

Core Research Program
U.S. ATLAS Operation Program



Phase-I

- Insertable b-layer (IBL):
  - ✓ TDR in preparation. Goal to be ready for installation in 2015
- **High rate muon chambers** for both trigger and precision position measurements
- ATLAS Forward Physics (AFP)
- Fast track-finder to supply Level-2 triggers (FTK)
  - ✓ Technical Proposal submitted to the Upgrade Steering Group (USG)
- Limited Level-1 Topological trigger

Micro-Pattern Gas Detector R&D for Forward Muon Spectrometer

- Several detector technologies have been proposed:Micromegas, GEM, Thin Gap Chamber (TGC), thin Monitored Drift Tubes (MDT)...
- **BNL is actively pursuing R&D on Micromegas in RD51 at CERN**
- BNL is coordinating the U.S. ATLAS R&D participation in RD51 with:

  ✓ U. of Arizona
  ✓ U. of South Carolina
  ✓ U. of Washington

People involved: G. de Geronimo, J. Fried, A. Hoffman, A. Kandasamy, K. Nikolopoulos, V. Polychronakos, V. Tcherniatine, E. Vernon

Core Research Program
U.S. ATLAS Operation Program
BNL overhead

- **Our goal is to develop in our Instr. Division at BNL a readout ASIC, appropriate for a variety of detectors**

  ✓ Fully data driven

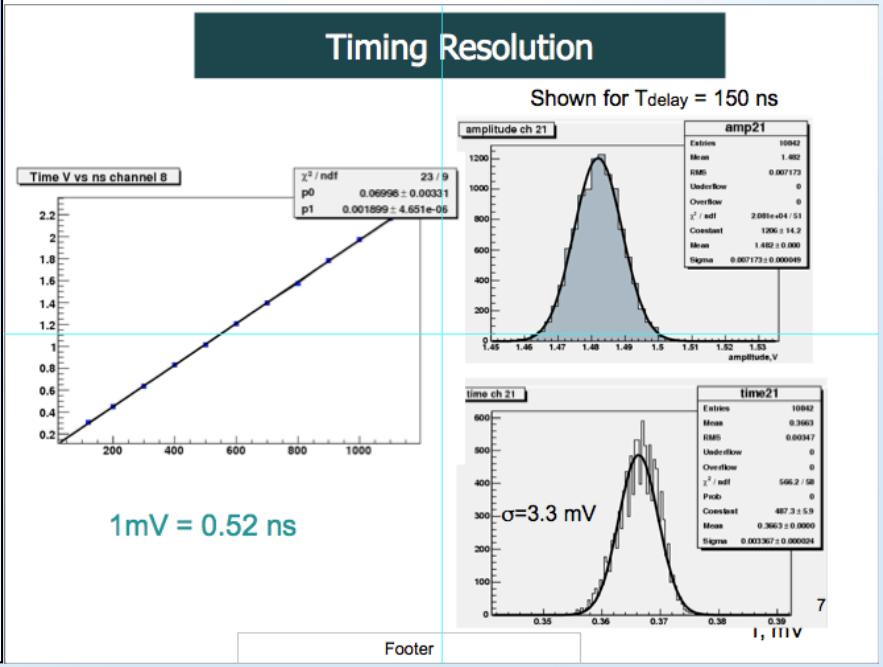
  ✓ Peak amplitude and time detection

  ✓ On-chip ADC (10-12 bits)

  ✓ Zero-suppression built-in

  ✓ Able to provide trigger primitives

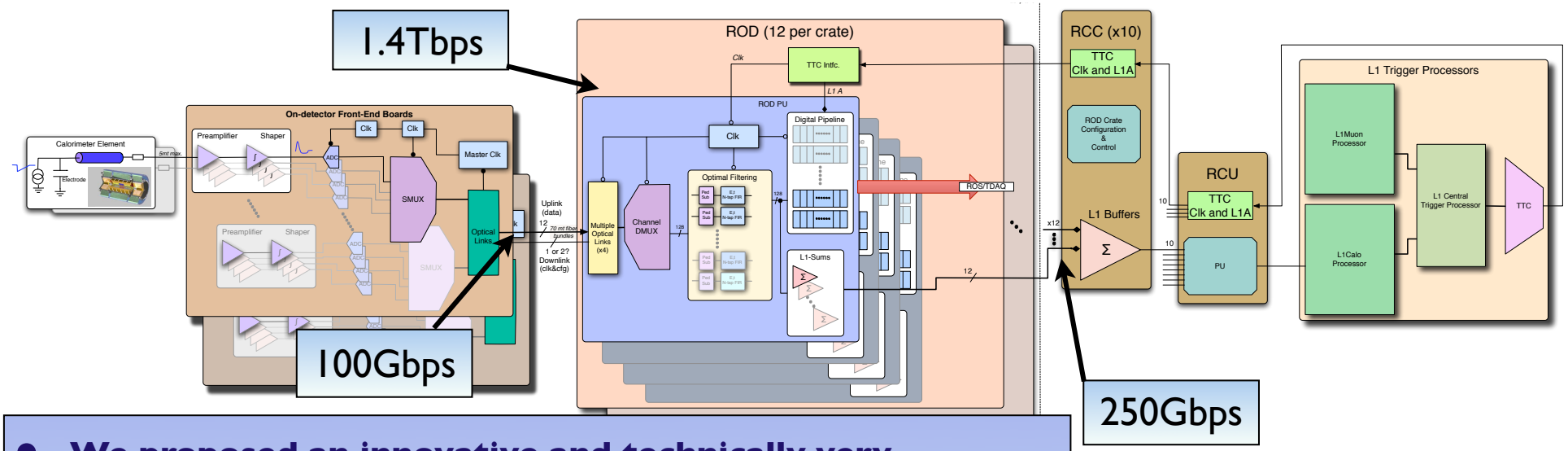
- *An existing ASIC with a similar architecture, but developed for another project, i.e. not optimized for the readout of Micromegas, was tested on a prototype at CERN with cosmics with promising performance.*



Additional projects considered for Phase-I

- ATLAS is considering to **bring some Phase-II upgrade projects forward** in order to:
  - ✓ Improve detector performance and boost physics discovery capabilities
  - ✓ Reduce tight and crowded schedule during the Phase-II shutdown
- Replace current pixel detector
- ***Sharpen Level-1 (L1) trigger thresholds at high luminosity:***
  - ✓ Bring the muon Monitored Drift Tubes (MDT) into L1 trigger
  - ✓ ***Full topological trigger***
  - ✓ **New calorimeter readout** (both LAr and Tile)
    - Can a coherent upgrade be made compatible with existing 3.2 μs L1 max. latency of the inner detector and of the muon system?
    - Can it be ready by 2016-2017?
- **ATLAS task forces will be setup to study all this by the end of the year.**

New Calorimeter Readout



- **We proposed an innovative and technically very challenging scheme to read out the calorimeters.**
  - ✓ capable of maintaining detector performance in a high pile-up environment from min. bias
  - ✓ improve trigger selectivity, which may boost discovery capabilities in physics searches
  - ✓ would allow hardware implementation of L2/HLT algorithms (reconfigurable computing)
- BNL is coordinating the ATLAS LAr upgrade program (FL is Deputy PL, also member of the USG)
- BNL is also coordinating the U.S.-ATLAS participation to this R&D with:
  - ✓ U. of Arizona
  - ✓ Columbia University
  - ✓ University of Pennsylvania
  - ✓ Southern Method University, Dallas

People involved: H. Chen, A. Hoffman, J. Kierstead, F. Lanni, J. Mead, S. Rescia, H. Takai, E. Vernon

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Phase-II

- The main phase-II program will be the complete replacement of the inner tracker (SCT and TRT) for $\mathcal{L}_{inst}>3x10^{34}cm^{-2}s^{-1}$ or $\mathcal{L}_{int}>500\text{-}700fb^{-1}$.
- On-going R&D at different levels:
  - ✓Si Sensors
  - ✓Front-End electronics
  - ✓Slow control (DCS), powering and **protection circuitry**
  - ✓**Module and stave assembly**
  - ✓Geometry, layout: modularity studies for better maintanability

Si-tracker R&D at BNL

- Our goal is to become one of two worldwide centers for final stave production for the barrel inner tracker.
  - ✓ Production, assembly and testing of 1/2 of the stave barrels
  - ✓ Protection circuitry for serial powering scheme
  - ✓ Possible participation to module production
- Collaboration with LBNL, Yale and NYU.
- Design of carbon-fiber composite stave cores
- Construction of "stavelets" to be used with real modules (collaboration w. UK groups)
- Development of measurement system of thermo-mechanical metrology for assembled staves (motor-driven IR scanning)
- Serial powering protection circuit prototypes
- Characterization of power devices intrinsically radiation hard (GaN, LDMOS)

People involved: R. Burns, S. Duffin, A. Gordeev, J. Kierstead, P. Kuczewski, D. Lynn, K. Sexton, M.-A. Pleier, S. Rescia

Core Research Program
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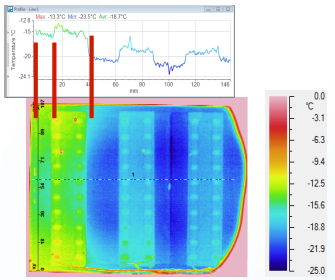
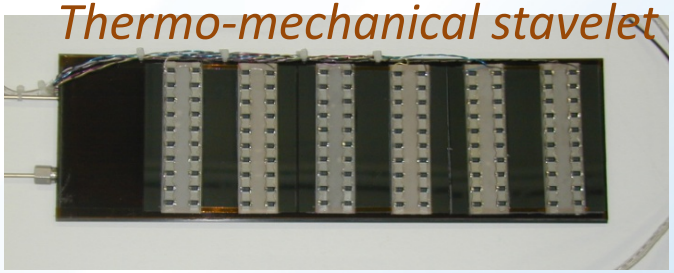


Thermo-mechanical stavelet



Manpower and Organization

- Minimal core of scientists supported through Core Research Program
- Support of technical personnel from the U.S. ATLAS Operation Program
- Leverage of Instrumentation Division resources (and C/A Dept. for LVPS)
- Synergies with the generic detector R&D program

LAr	Muon	Silicon IT
F. Lanni: 0.7	V. Polychronakos: 0.4	D. Lynn: 1.0
H. Takai: 0.8	K. Nikolopoulos: 0.1	M.-A. Pleier: 0.5
H. Chen: 0.4	V. Tcherniatine: 0.3	S. Duffin 0.1
J. Kierstead: 0.1	A. Hoffman 0.1	A. Gordeev 0.15
J. Mead: 0.4	G. de Geronimo	J. Kierstead 0.25
S. Rescia: 0.3	E. Vernon	P. Kuczewski 0.5
E. Vernon	J. Fried	K. Sexton 0.5
	A. Kandasamy	R. Burns 0.5
		S. Rescia

Core Research Program
U.S. ATLAS Operation Program
BNL overhead

Synergies with other programs

- **We have a proven track record to take on these upgrade projects allowing for long-term improvements in detector performance and physics reach.**
- **Two key factors:**

1. Support from the Operation Program for technical personnel.
   - ✓ Likely to change in the near future
   - ✓ We will compete in the new national program for R&D at collider experiments for the support of our technical expertise
2. **Synergies with the generic detector R&D program, LDRDs and local expertise (e.g. Instrumentation).**
   - ✓ Continuous cross-breeding between generic detector and collider experiment R&Ds.
   - ✓ Motivate new ideas and developments
   - ✓ Provide solutions for a variety of fields of application

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- **LAr R&D**
  - ✓ High Data Throughput, FPGA based solutions for signal processing and feature extraction.
  - ✓ Reconfigurable Computing for DAQ and trigger purposes
- Possible applications:
  - ✓ Large volume imaging detectors (LAr TPC, MicroBooNE),
  - ✓ Photon science experiments and instrumentation at light sources:
    - ✓ X-Ray Pump Probe (XPP) experiment @ LCLS at SLAC
    - ✓ Beam position monitor for NSLS2
  - ✓ Next generation high resolving power calorimeters, real time particle flow algorithms etc...(eRHIC, ILC, muon coll.)?

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- **Muon CSC**
  - ✓ Possible use in μ→e experiments
  - ✓ Extend response to high flux and high repetition rates
  - ✓ Micro-pattern gas detector R&D: GEMs, Micromegas
- **Silicon Inner Tracker:**
  - ✓ Large area trackers, large integration, powering schemes
  - ✓ ILC applications

Summary: Near Term Goals (2010-2012)

- **For 2010-2012/3 our priority is to lead the R&D efforts which will provide the technical solutions to the challenges of ATLAS at high luminosity in the 3 selected areas:**

1. Maintain and strengthen our leadership in the LAr Upgrade Program.

   ✓ Lead the R&D program in overall ATLAS
   ✓ Define the Readout Architecture
   ✓ Solve the technical challenges in both Front-End and Back-End.

2. Participate in the Micromegas R&D program at CERN for the Muon Spectrometer

   ✓ Lead development of the front-end readout for the entire Muon upgrade

3. Maintain a leadership role in the R&D for the Silicon Strip Tracker replacement.

   ✓ Become a national center in the U.S. for the stave and barrel assembly

- Strengthen collaboration with U.S. university groups, support their R&D program with our infrastructure
- Strengthen BNL role as a major center of detector R&D for the U.S. community

Summary: Long Term Strategies (2013 and beyond)

- **Long term strategies @ BNL will depend on the OHEP future support for U.S. ATLAS participation in upgrades**

  ✓ We have been in the favorable position within ATLAS of having a strong and influential role in the whole ATLAS collaboration. The U.S.-ATLAS scientific community benefitted from it.

  ✓We are actively engaged in the definition of the future ATLAS strategies and priorities (ATLAS USG). We are pursuing the means to do it in the future.

  ✓We are eager to compete in the future national R&D program for collider experiments for the technical support required

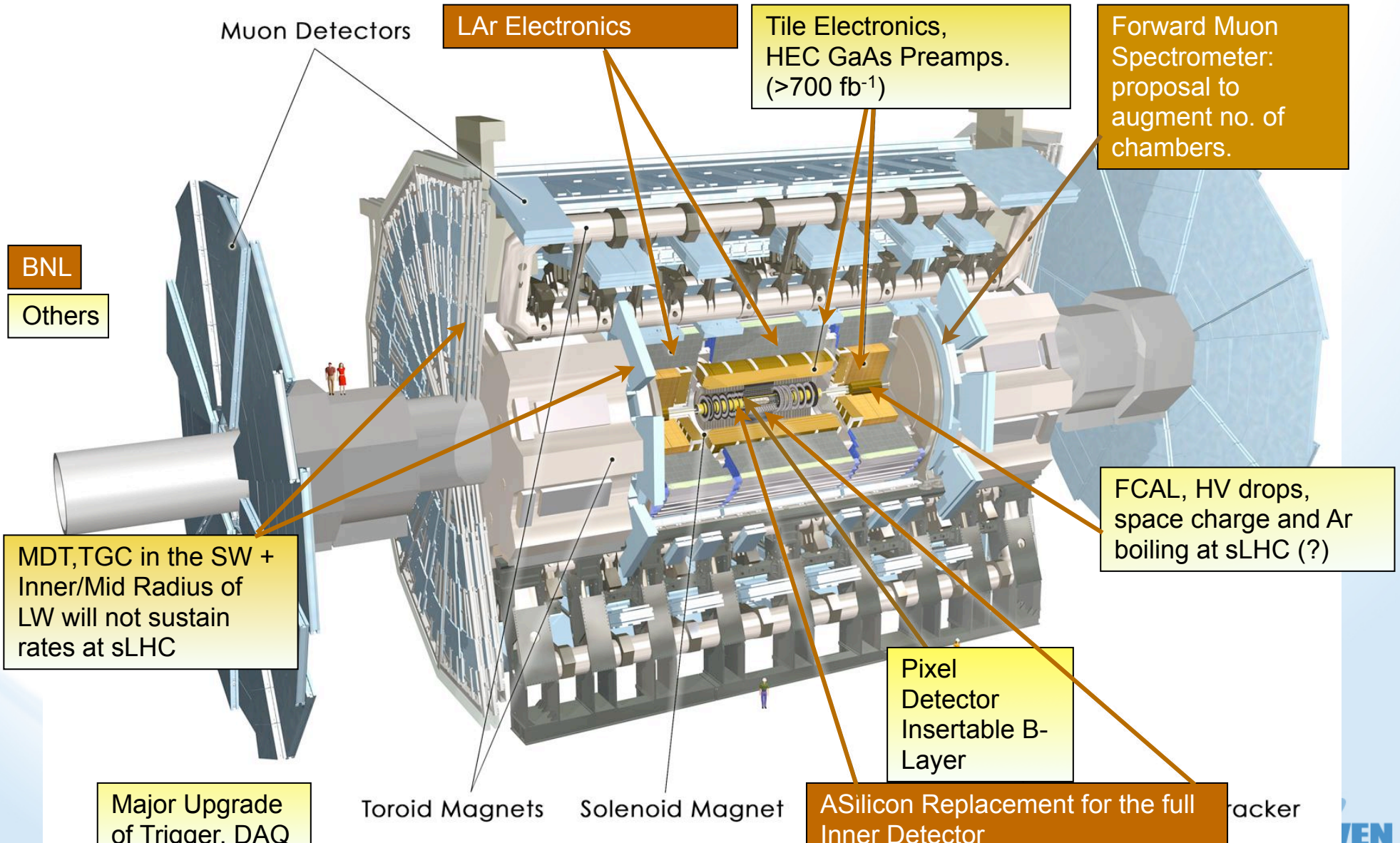
  ✓We carefully selected areas of interests based our local expertise (e.g. Instr.), other existing generic detector R&D programs in BNL and ultimately our capabilities of steering and influencing ATLAS strategies on the long term.

Summary: Long Term Strategies (2013 and beyond)

- Long term strategies will have to be tuned also with:
  - ✓ LHC schedule
  - ✓ **Physics results from the 7 TeV run. *Our capability today of running essential analysis at 7 TeV will be critical to understand detector issues at high luminosity***
    - *Background rates and understanding of the real limits of different detector components.*
    - *System and overall ATLAS performance + impact on the physics program*
- **Current personnel on the core research program is sufficient only to carry on basic R&D in the short term.**
- **With the current guidelines (1FTE reduction) we'll be able to carry 2 projects out of 3 (temporary redirection or scope reduction among the options)**
- R&D programs will mature to construction around 2013.
  - ✓ Need ~1.5 FTEs support from the core research program for each project
  - ✓ and adequate support by project funds for technical personnel
- **Expected decisions around 2012-3.**

Backup Slides:
Details of the R&D programs @ BNL

BNL Plans for ATLAS Upgrades



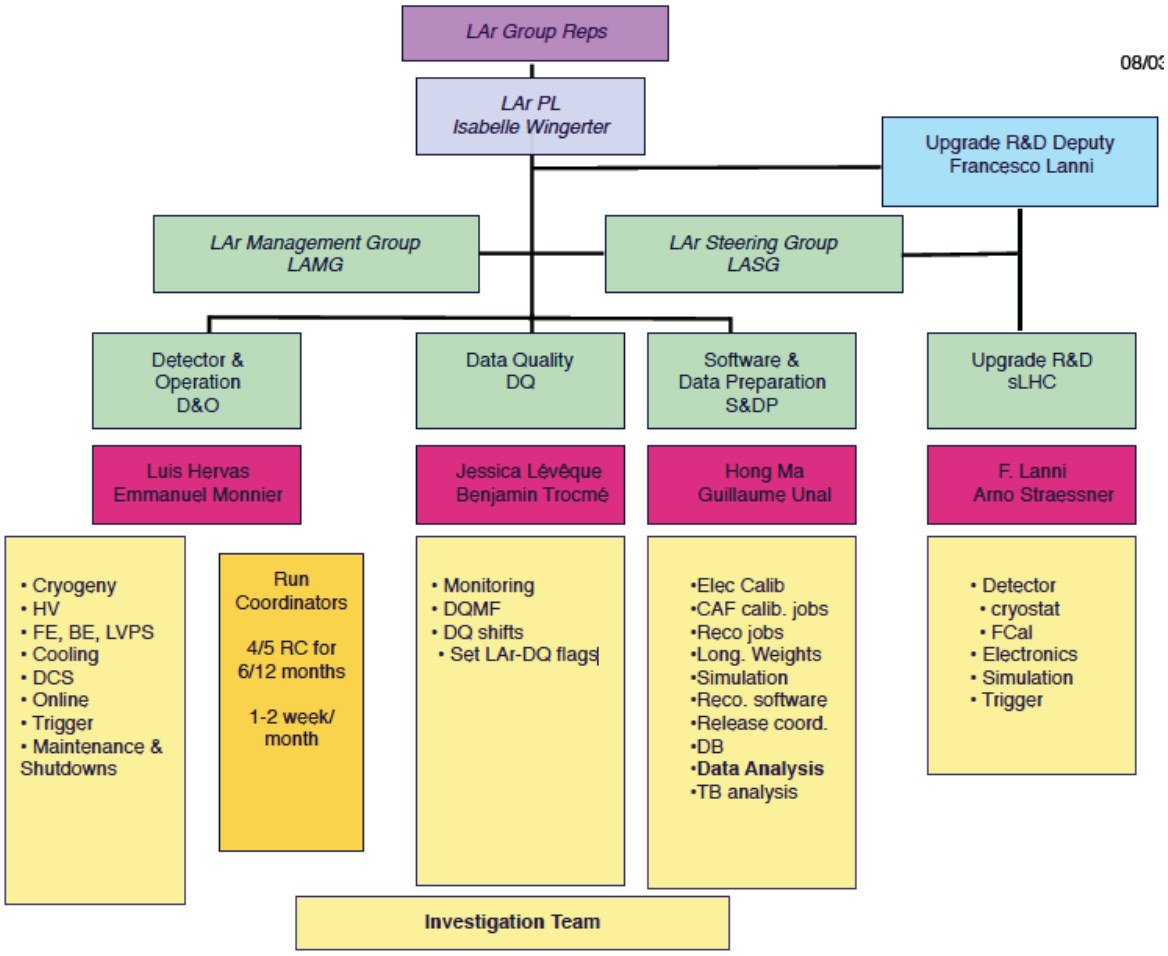
BNL Plans for ATLAS Upgrades

Interest of our groups in the ATLAS upgrade in areas with local, widely recognized expertise

- **Liquid Argon calorimeter**
  - ✓ *BNL has lead the development of noble liquid detectors since its inception*
  - ✓ *Helios, D0, SSC-GEM, ATLAS... just a few examples*
- **Muon Spectrometer**
  - ✓ *Development of CSC as large area, high precision position detectors has been made at BNL*
  - ✓ *Technology widely used in many HEP/NP (e.g. all 4 LHC experiments)*
- **Silicon Inner Tracker**
  - ✓ *Instrumentation Division leading the development of radiation resistant Silicon sensors.*
  - ✓ *Experience of system assemblies from previous BNL experiments (P238 at SPS, E896 at AGS, STAR-SVT at RHIC, PP2PP at RHIC)*
  - ✓ *Potential availability of large infrastructures needed for stave assembly and module production*

LAr Calorimeter Upgrades

- Our contribution to the LAr calorimeters has been traditionally the strongest one since BNL joined ATLAS.
- Many responsibilities during construction and early commissioning.
- Today in LAr we have key roles in data preparation, combined performance, detector operations and mgmt. (see Hong/Srini presentation).
- ***FL is the LAr deputy project leader for upgrade is from BNL (Mar-2010)***
- ***Also member in the ATLAS Upgrade Steering Group (~2005-)***



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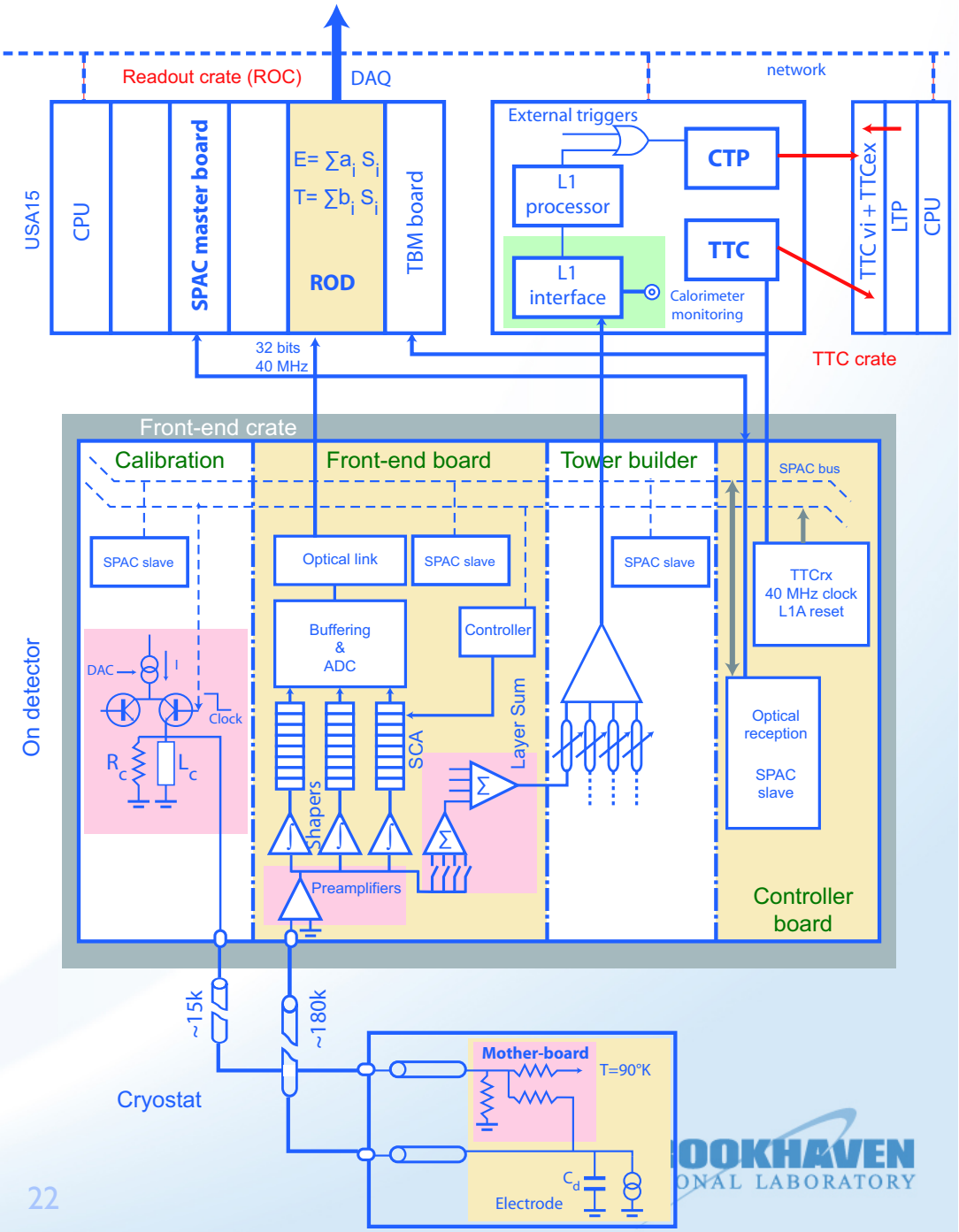
LAr Calorimeters Readout

- On-Detector Readout
- 1,600 Front-End Boards:
  - ✓Preamplifier/Shaper
  - ✓Analog Pipelines (SCA)
  - ✓ADC+Gain Selector
  - ✓MUX+Optical Links
- Tower Builders for L1-trigger
- Precision Electronics Calibration

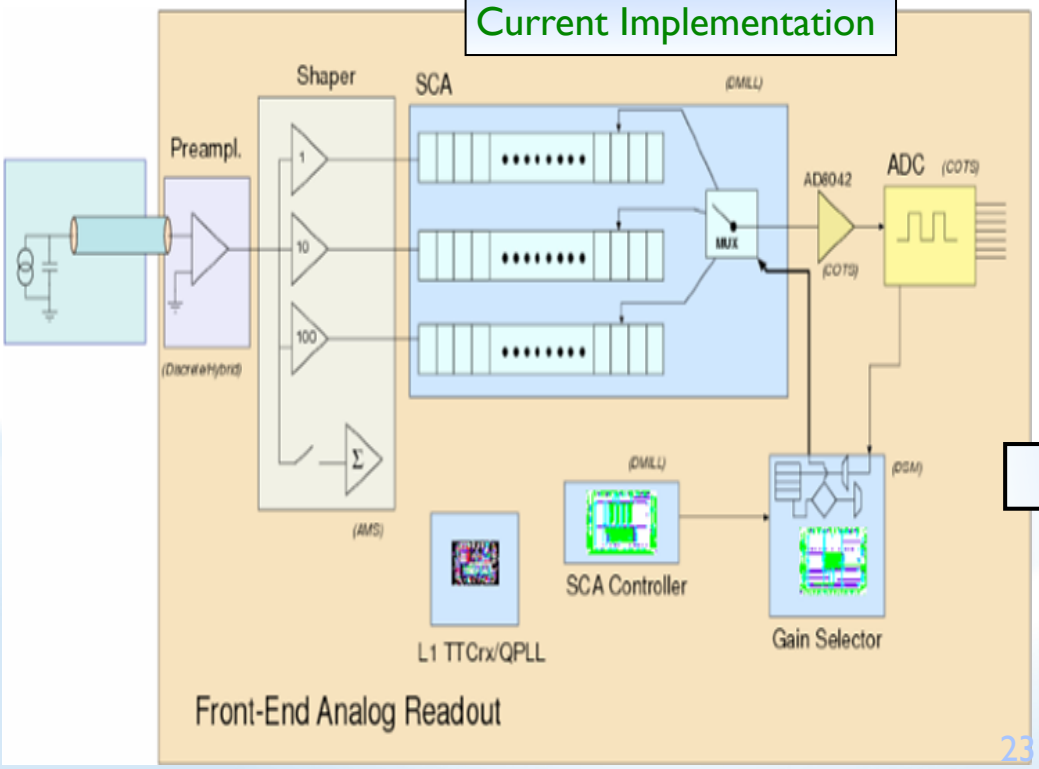


Readout Upgrade: Motivation

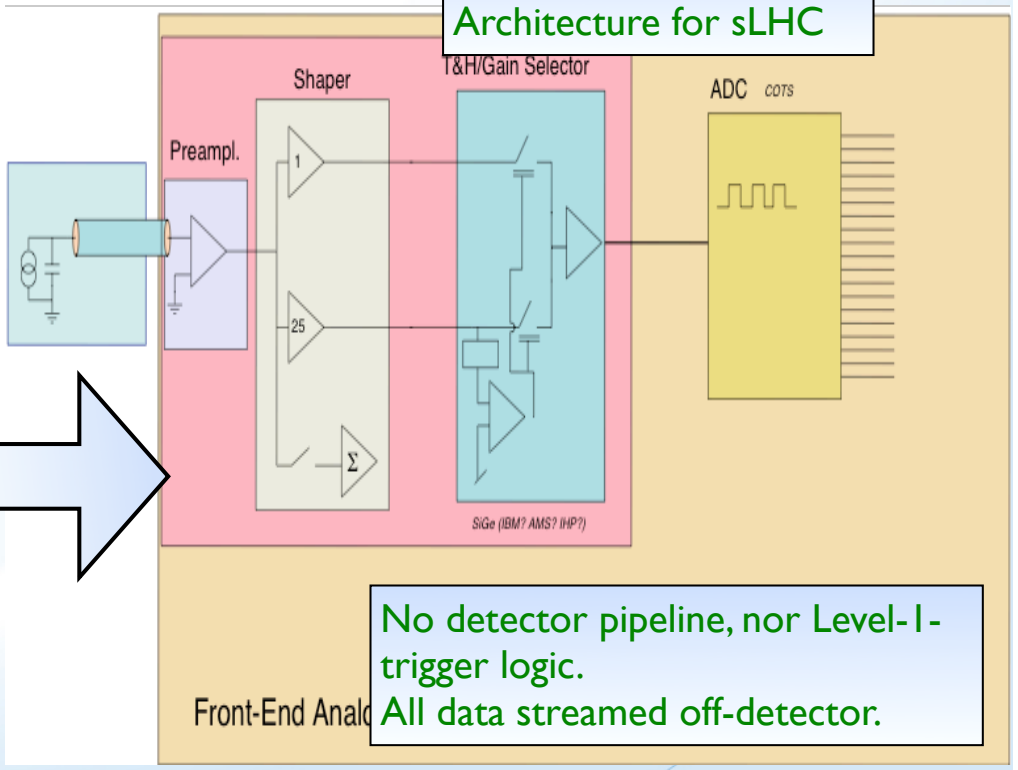
- The current Front-End is designed for 10yrs of operations @ 10^{34}
  - ✓ It is based on 13 ASICs w. different technologies, some are already obsolete and not available.
  - ✓ Partial upgrade is not conceivable.
- Aging of some of the components is expected.
  - ✓ Very small number of components.

- BNL is leading an effort to define a new readout architecture in collaboration with several EU institutions and U.S. universities:
  - ✓ Columbia Univ.
  - ✓ U. of Pennsylvania
  - ✓ Yale Univ.
  - ✓ Southern Method Univ.
  - ✓ U. of Arizona

Current Implementation



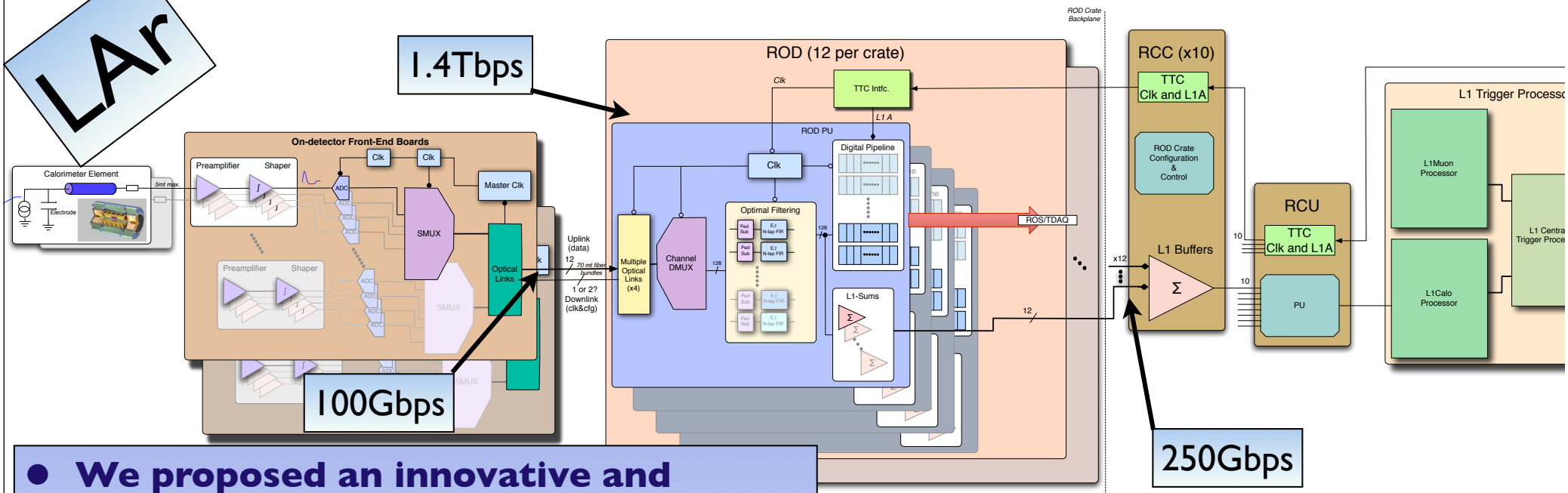
Proposed Baseline Architecture for sLHC



No detector pipeline, nor Level-1-trigger logic.
All data streamed off-detector.

Readout Architecture Studies

LAr



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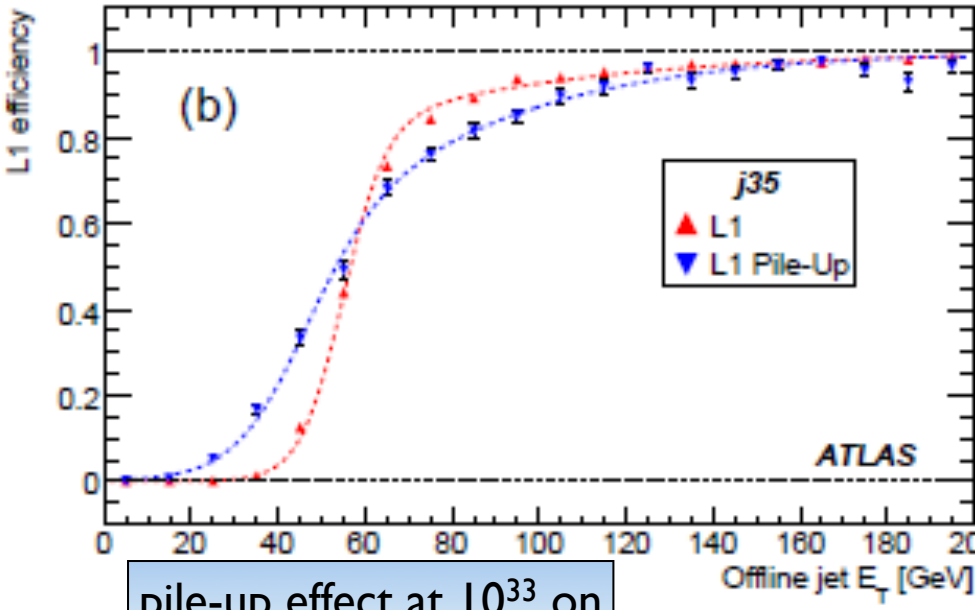
  - ✓ capable of maintaining detector performance in a high pile-up environment from min. bias
  - ✓ improve trigger selectivity, which may boost discovery capabilities in physics searches
  - ✓ would allow hardware implementation of L2/ HLT algorithms (?)
- **Now is being considered by ATLAS as "potential" early upgrade (if data will confirm the MC predictions).**

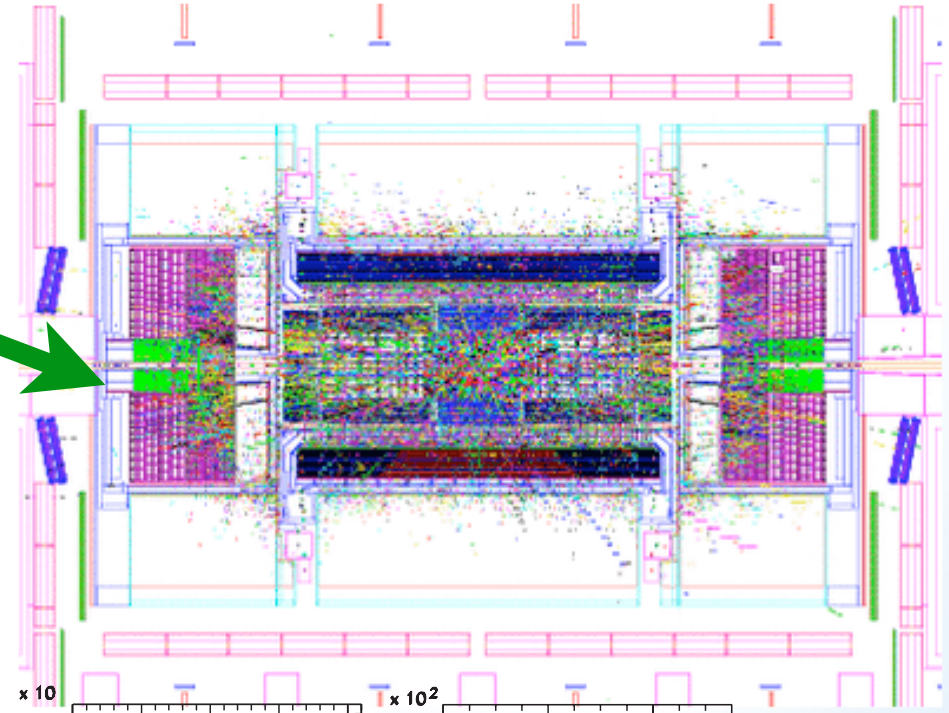


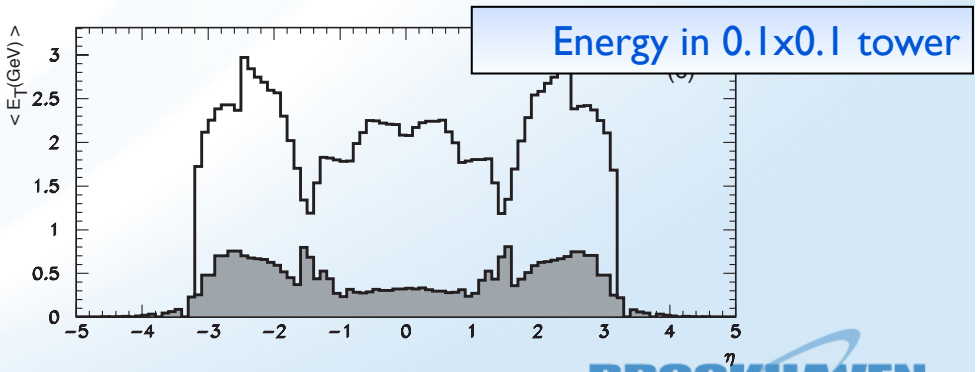
pile-up effect at 10^{33} on jet trigger L1-efficiency

Pile-up Studies

At the sLHC severe challenges for the calorimeter readout and performance.

- Pile-up study essential for the definition of the readout architecture and of its parameters.
  - ✓Noise (in time and out)
  - ✓Impact on electronics: effective dynamic range, signal processing...
- **H. Takai leading this study in ATLAS LAr. Collaboration with U. Arizona and U. Dresden (Germany).**





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Front-End Electronics

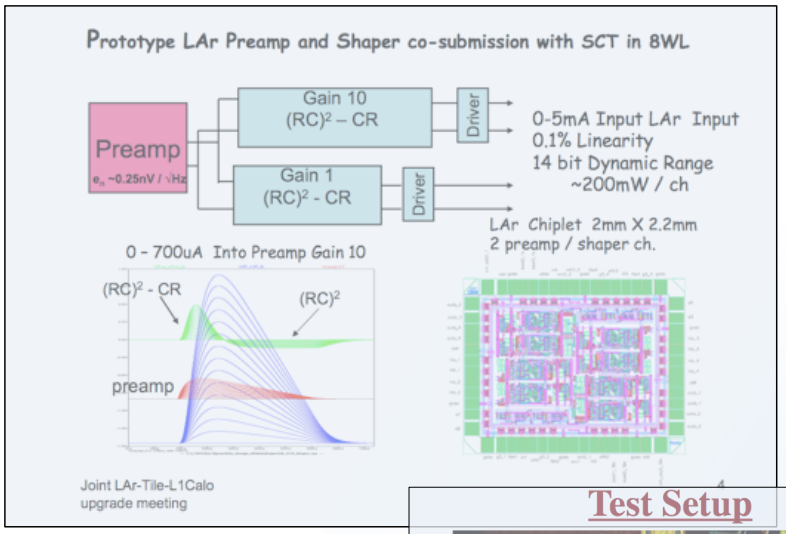
- R&D Scope:
- Analog Front-End Integration with SiGe processes

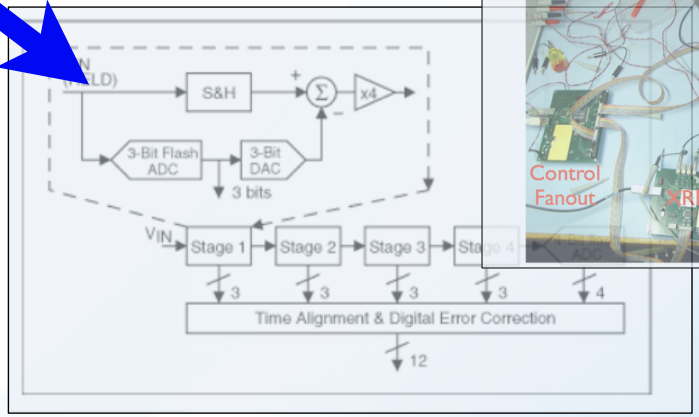
  ✓BNL and U. Penn.
- Custom ADC Design in .13um CMOS process

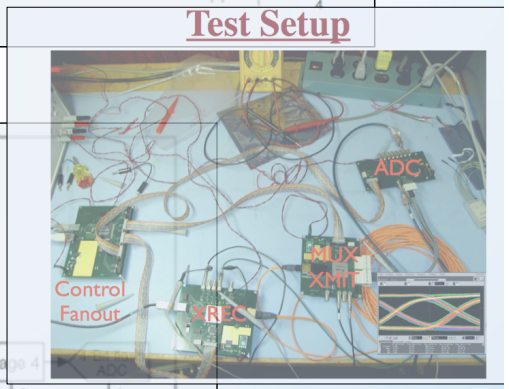
  ✓Columbia Univ.
- MUX + Optical Link in Silicon on Sapphire.

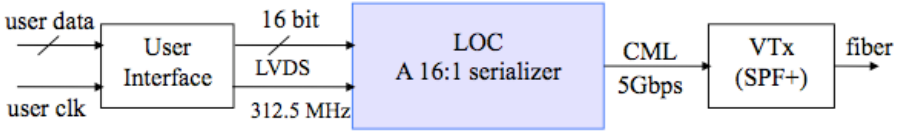
  ✓SMU (w. BNL help)
- Power supplies and distributed point of load regulators

  ✓BNL and Yale Univ.









Analog Front-End

- Development of an ASIC in IBM SiGe BiCMOS technology

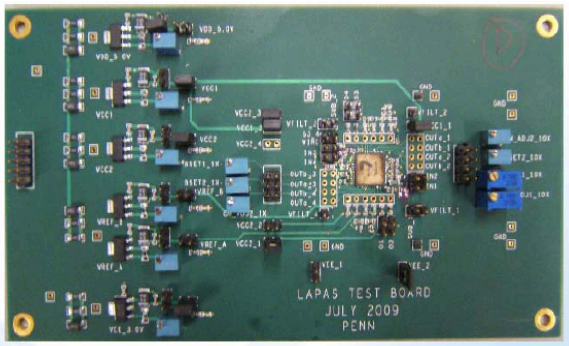
  ✓ Preamplifier and Shaper

- Preampl. design based on low noise line-terminating circuit topology
- High breakdown devices allow for higher swing to accommodate full 16-bit dynamic range

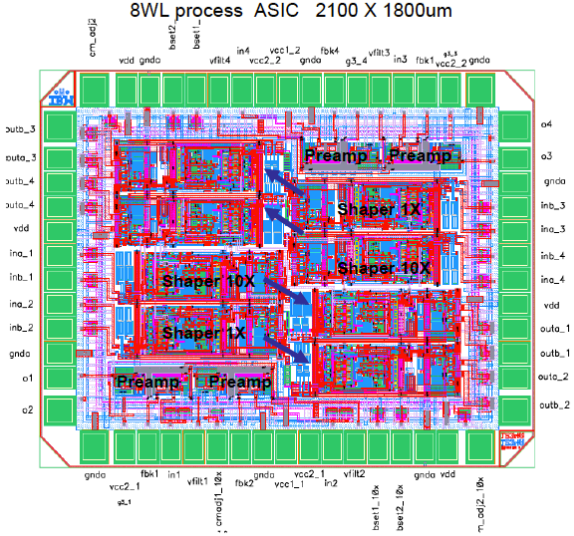
Serial noise power density en~0.26nV/√Hz
ENI=73nA RMS (including 2nd stage and for Cd=1nF) P = 42mW

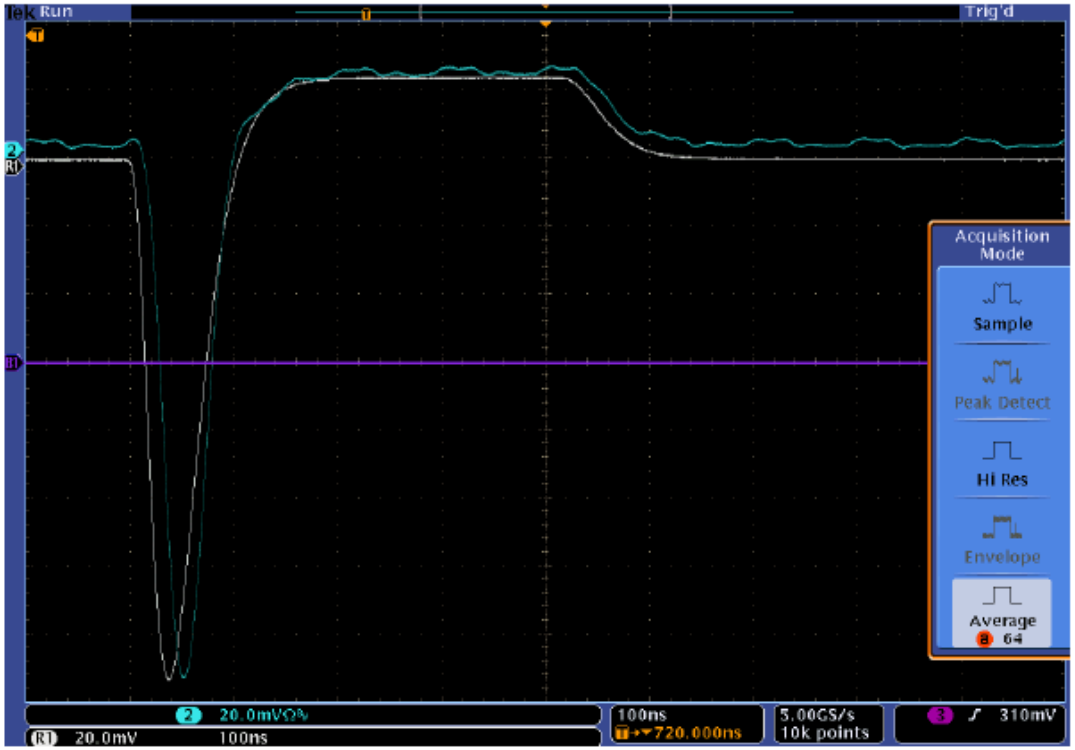
- Characterization complete: performance as expected
- Collab. with U. Penn. and INFN-Milan

Test Printed-Circuit Board



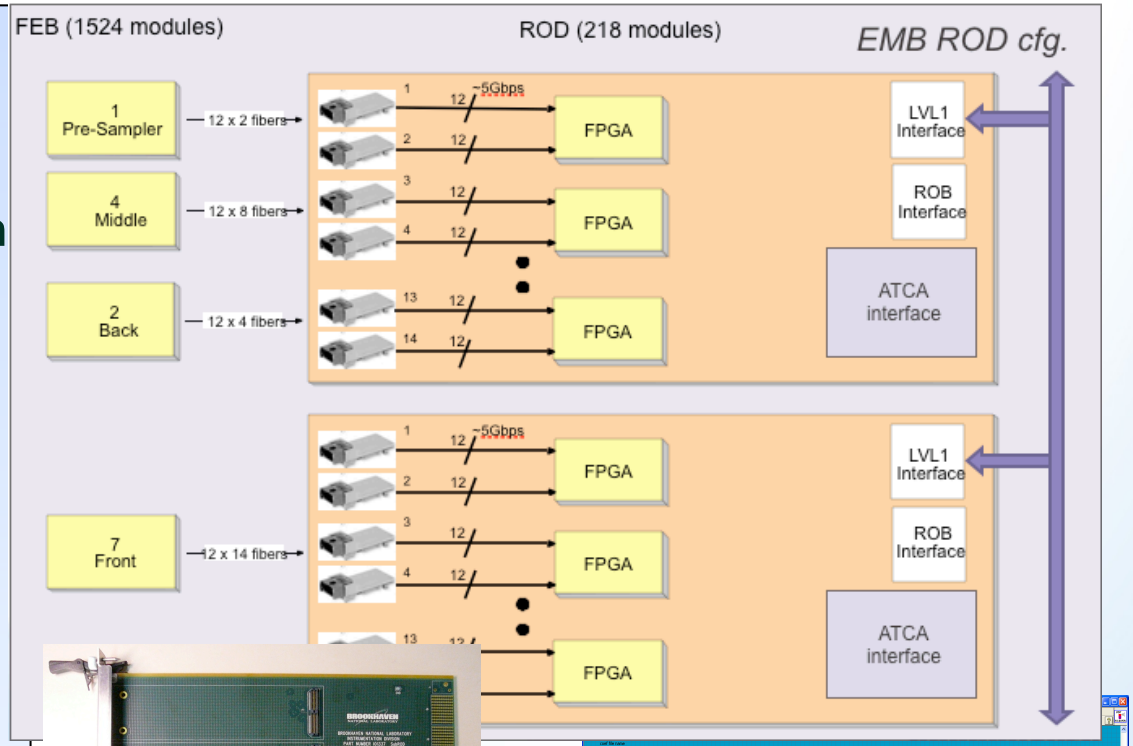
LAPAS: Liquid Argon PreAmplifier Shaper
8WL process ASIC 2100 X 1800um

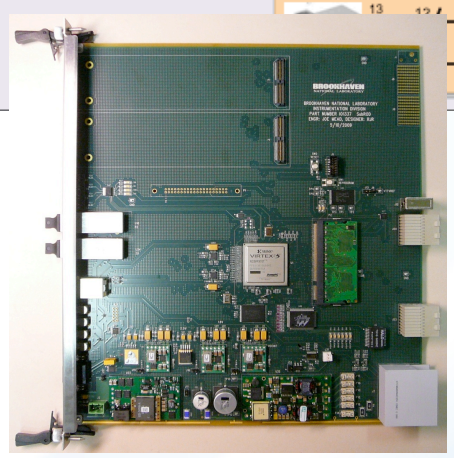


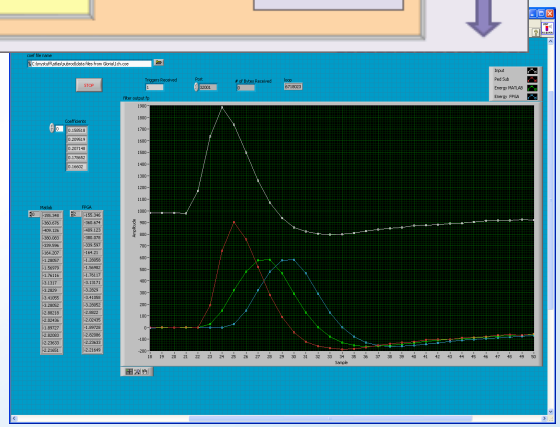


ReadOut Driver (ROD) Upgrade

- R&D Objectives:
  - ✓ Process continuously digitized detector signals, extracting E,t in real-time and ....
  - ✓ provide Level-1 Trigger functionalities on ROD
  - ✓ Evaluate several critical technologies for the next generation ROD
- R&D Scope:
  - ✓ High density/High speed optical links and FPGA serializers
    - LAr Entire bandwidth > 150Tbps
  - ✓ Low latency lossless data compression algorithms
  - ✓ FPGA based Digital Signal Processing



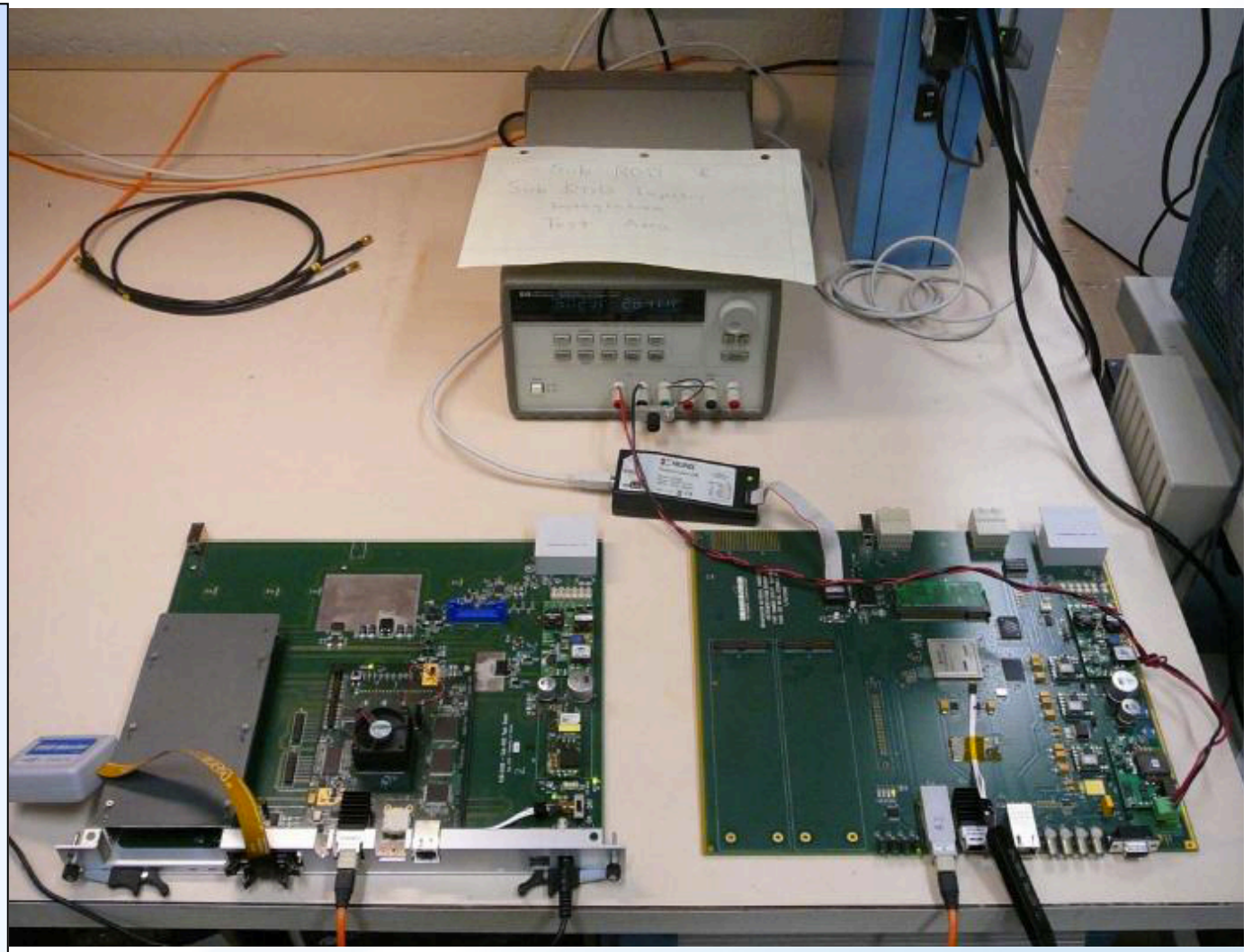




- **Energy Calculation Test Bench**
- **Apply Optimal Filtering Coefficients with latency of only 2 bunch crossings**
- **Compare with floating point calculation, quantization error is < 0.02%**

ReadOut Driver (ROD) Upgrade

- ROD architecture for R&D: ATCA shelf system and board form factor
- Integration tests @ BNL + U. of Arizona
  - ✓ ROD injector and ROD prototype in ATCA format
  - ✓ Tested with Xilinx V5 and Altera Stratix II links at up to 6.25Gbps
  - ✓ Tested FIR + Energy sum
  - ✓ Work on operating SNAP12 @ 75 Gbps
- Currently developing in AMC mezzanine format

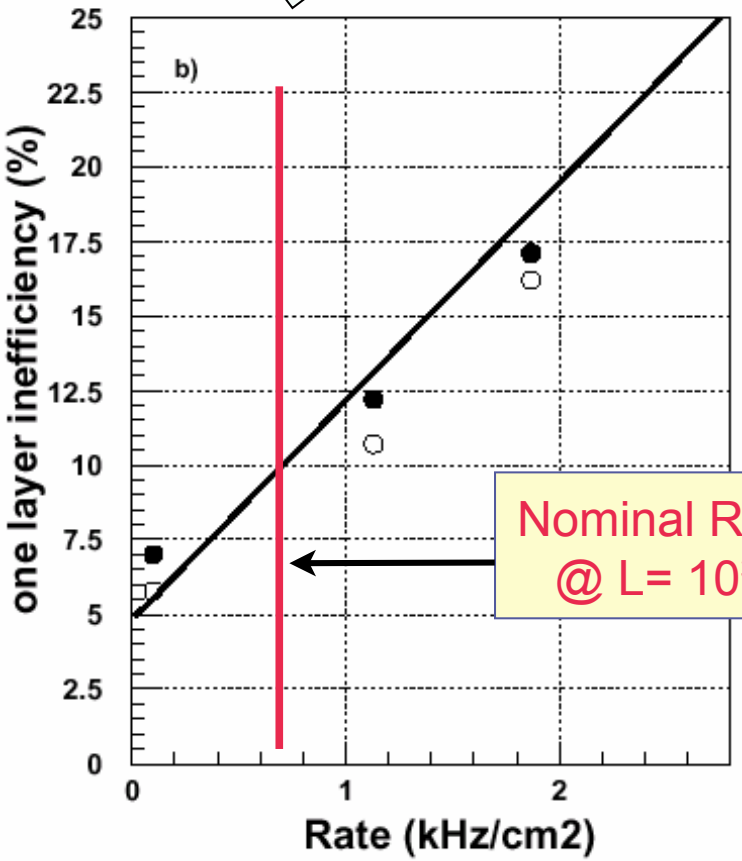


Near Term Goals

- We want to continue our R&D activities continue over the next 3 years:
  - ✓ Coordination and mgmt of ATLAS LAr and U.S.-ATLAS LAr
  - ✓ Readout Architecture definition
  - ✓ Study the impact on trigger and the physics case for a full digital readout of the calorimeters
  - ✓ Performance study of an upgraded LAr detector
  - ✓ Prepare for production of both Front-End and Back-End electronics
- We expect engineering and technical resources to be provided by the U.S.-ATLAS Operations Program and through the Instrumentation Division.

Motivations

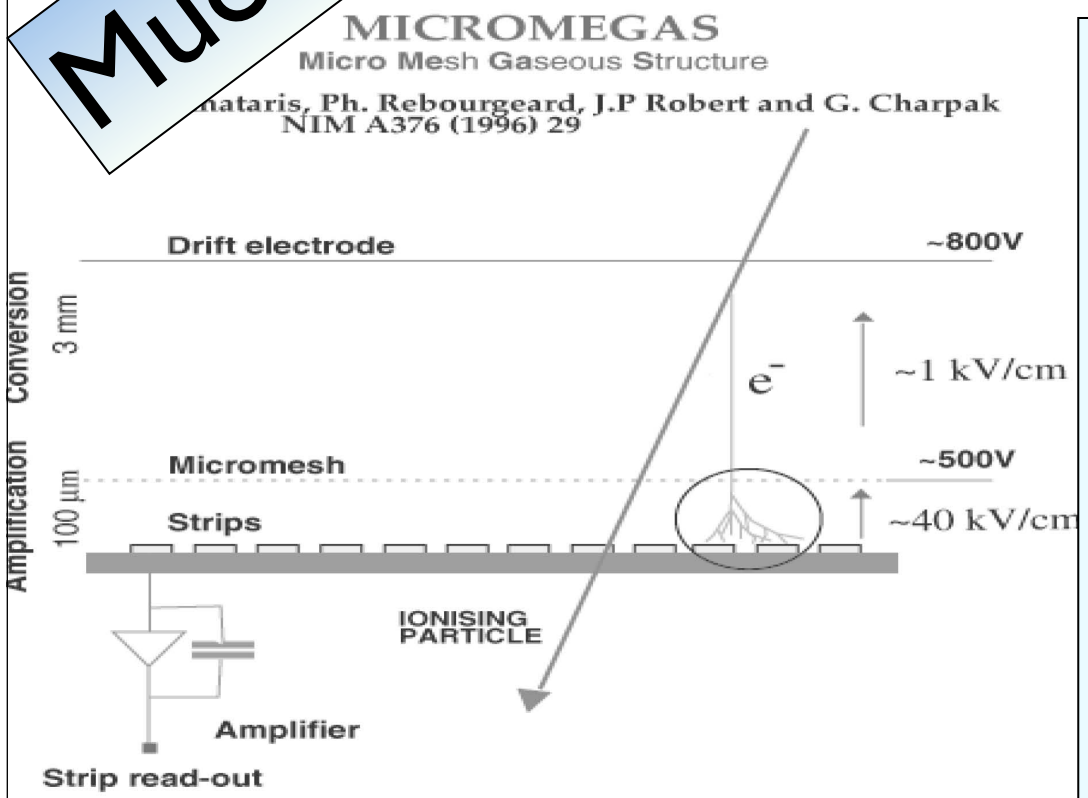
Muons

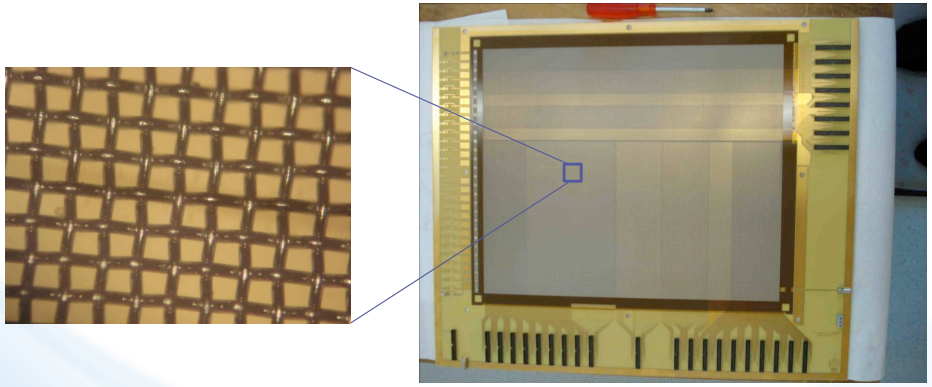


- The design of the detectors and readout of the Muon spectrometer is driven by cavern background rates as opposed to direct interaction products:
  - ✓Cavern backgrounds could be as much as x5 higher.
  - ✓End of this run we will be able to assess the situation more precisely
- Even for nominal rates a x3 increase in luminosity makes the operation of the CSC chambers marginal
  - ✓Need 8-layers in the forward region (as in the original design) sometimes after Phase-II.

R&D on Micromegas

Muons



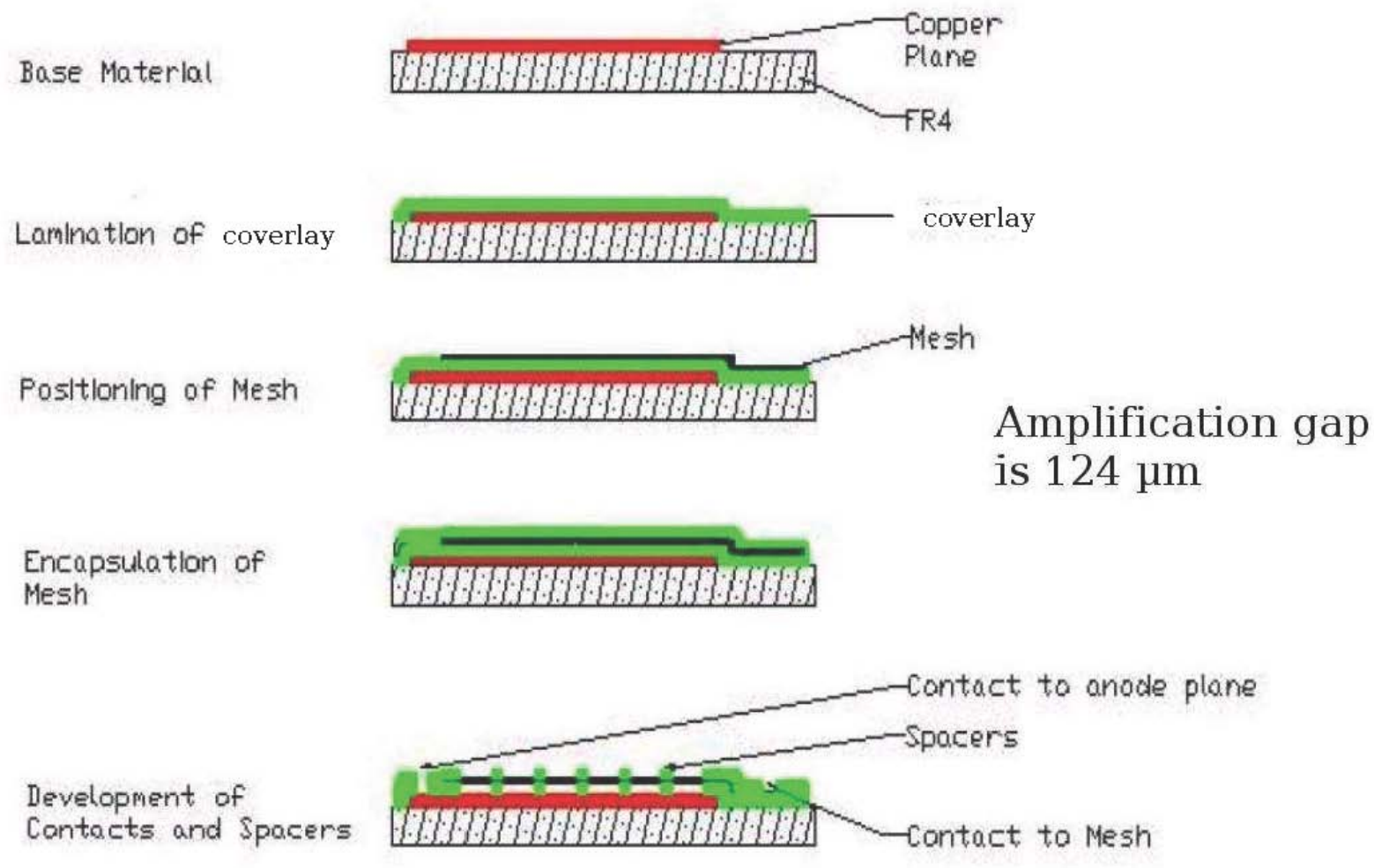


- To address the challenge BNL joined CERN-RD51 aimed at streamlining R&D work on Micro-Pattern Gas Detectors (GEM and Micromegas)
- Bulk Micromegas are attractive because they are based on an industrial process and scalable to the large size a muon detector requires.
- They offer a promising technology for large area, high rate/resolution detectors for a variety of applications (i.e. covering the needs of all ATLAS Muon for both Phase-I and II)
- BNL is coordinating the U.S.-ATLAS R&D participation in RD51 with:

✓ U. of Arizona
✓ U. of South Carolina
✓ U. of Washington

- A First Prototype was built at CERN and exposed successfully on testbeam in 2008.

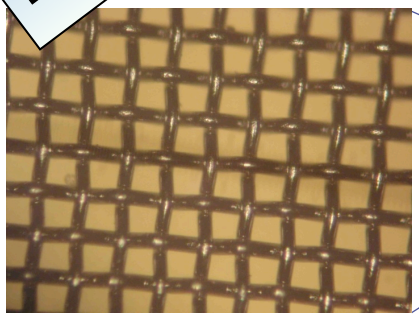
Muons Muon Upgrades: R&D on Micromegas

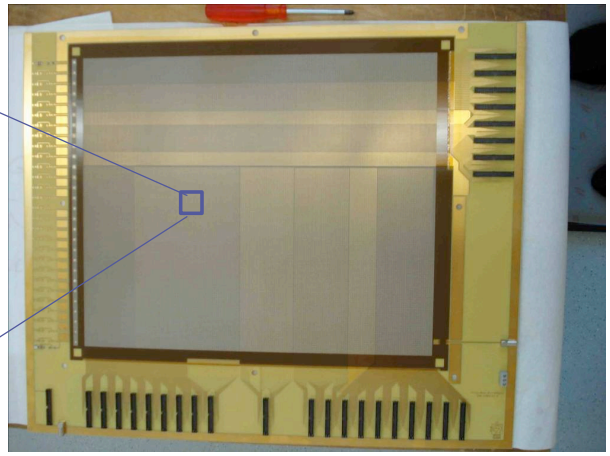


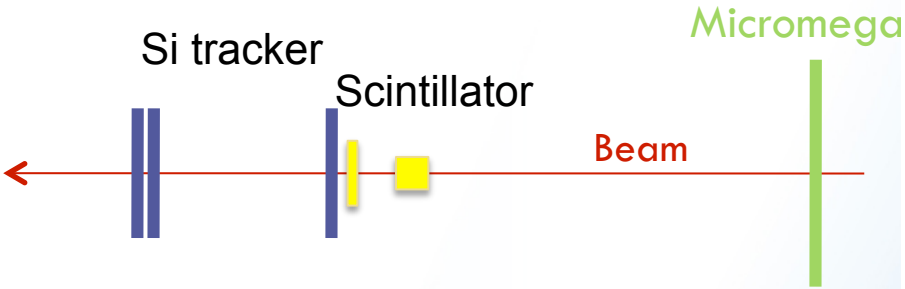
PRODUCTION SEQUENCE OF A BULK MICROMEGAS

Muons

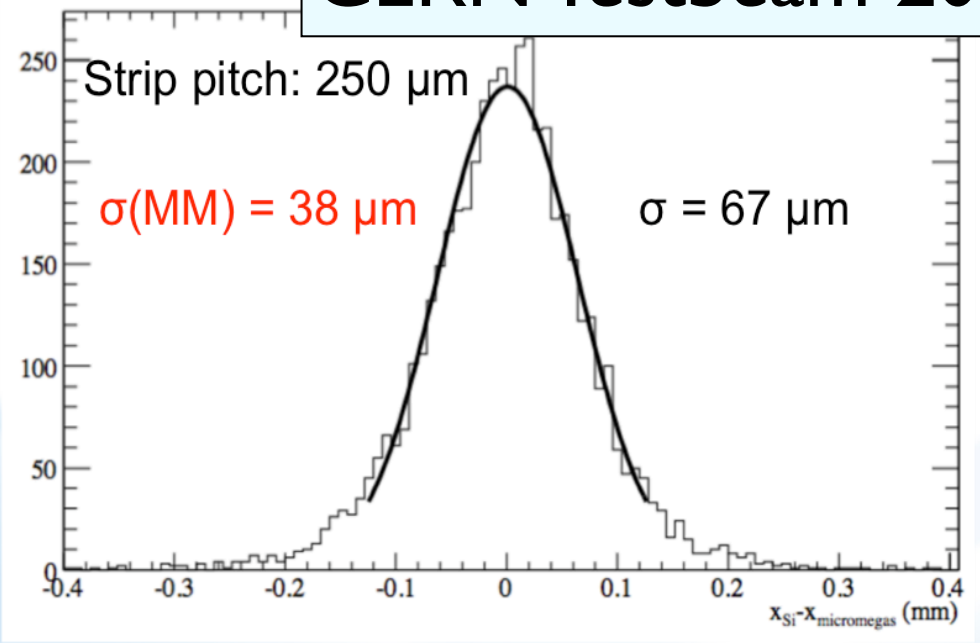
...on Upgrades: R&D on Micromegas (MM)







CERN Testbeam 2008



- Residuals of MM cluster position and extrapolated track from Si
- Convolution of:
  - Intrinsic MM resolution
  - Tracker resolution (extrapolation)
  - Multiple scattering

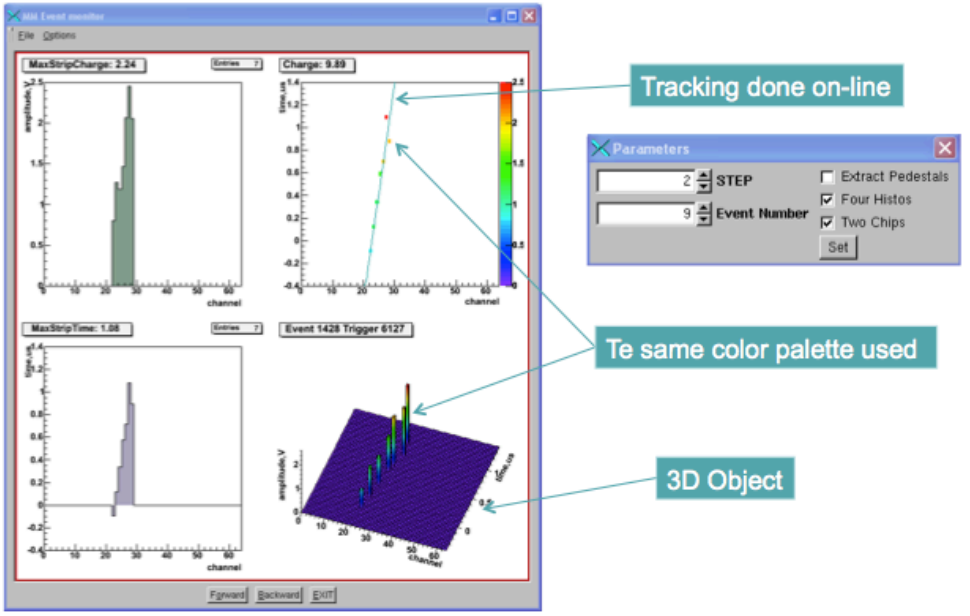
Recent accomplishments

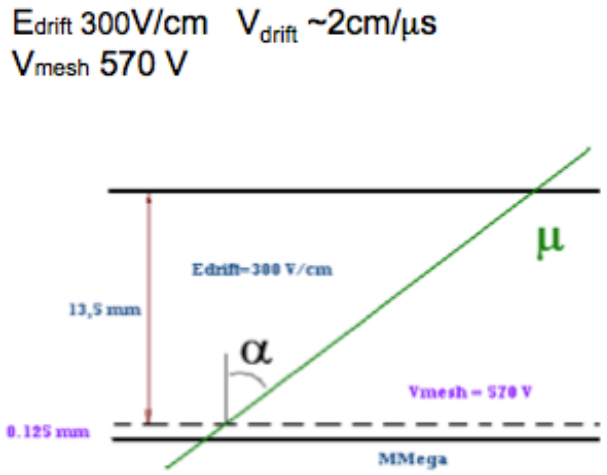
- Micromegas 2nd prototype equipped with a previously designed ASIC from BNL

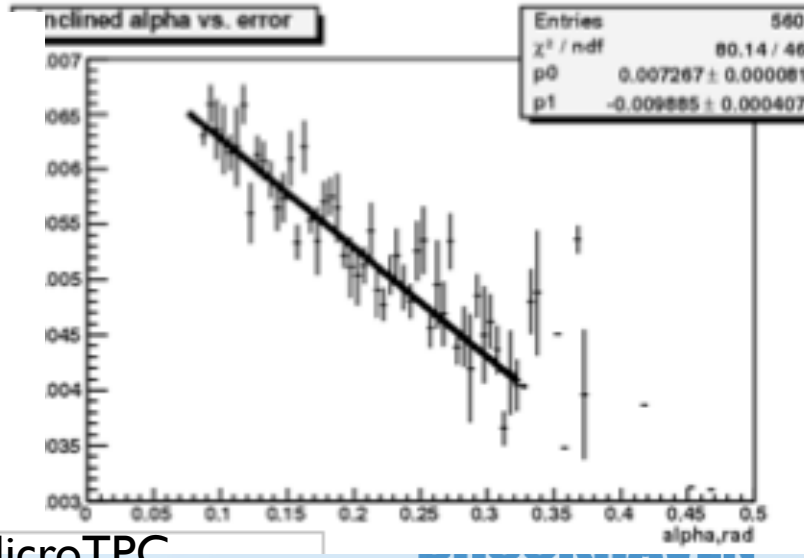
✓Tests with cosmics @ CERN

✓to be exposed to beam-test at the CERN SPS

Event Display







U.S.e of Micromegas as MicroTPC

Muons

Recent accomplishments

- Micromegas 2nd prototype equipped with a previously designed ASIC from BNL

✓Tests with cosmics @ CERN

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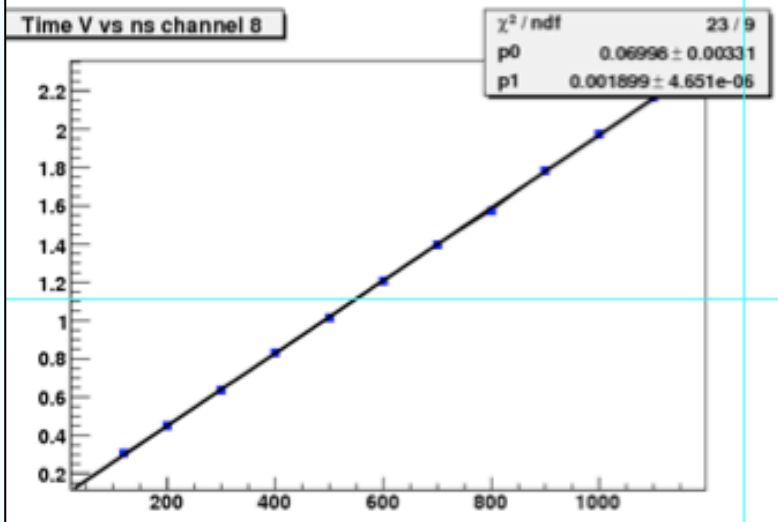
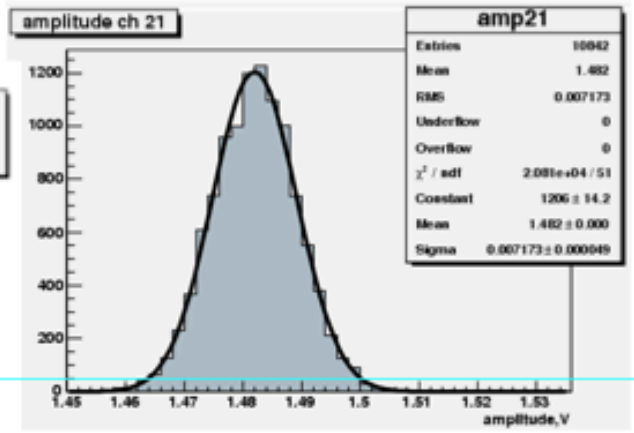
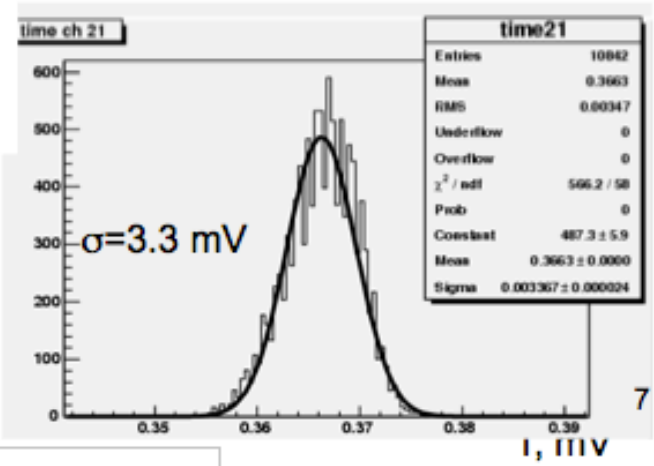
Timing Resolution

Shown for T_{delay} = 150 ns







1mV = 0.52 ns

Footer

Near Term Goals

- On the longer term we want to develop a fro
  ASIC appropriate for a variety of detectors
  (Micromegas, TGC, GEM...)

Muons

- Readout ASICs are being developed in our Instrumentation Division at BNL.
  - ✓Fully data driven
  - ✓Peak amplitude and time detection
  - ✓On-chip ADC (10-12 bits)
  - ✓Zero-suppression built-in
  - ✓Able to provide trigger primitives

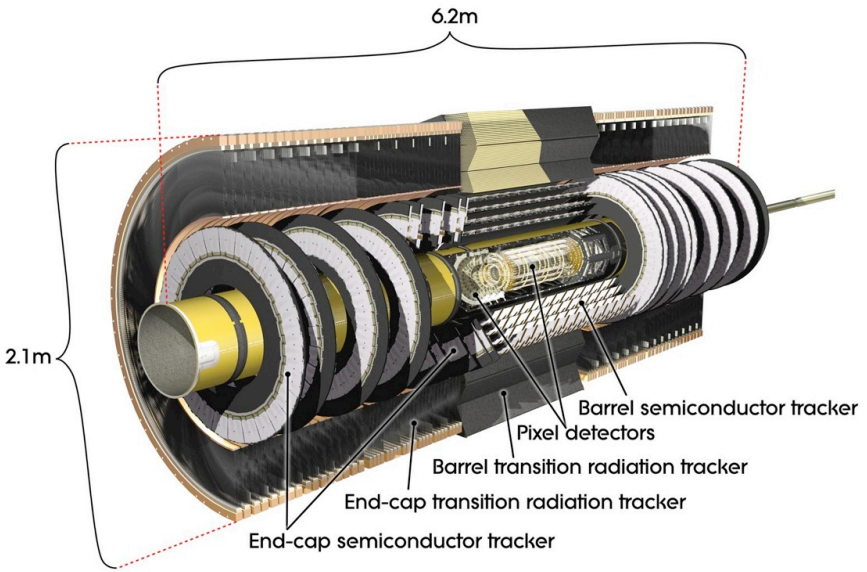
Silicon IT

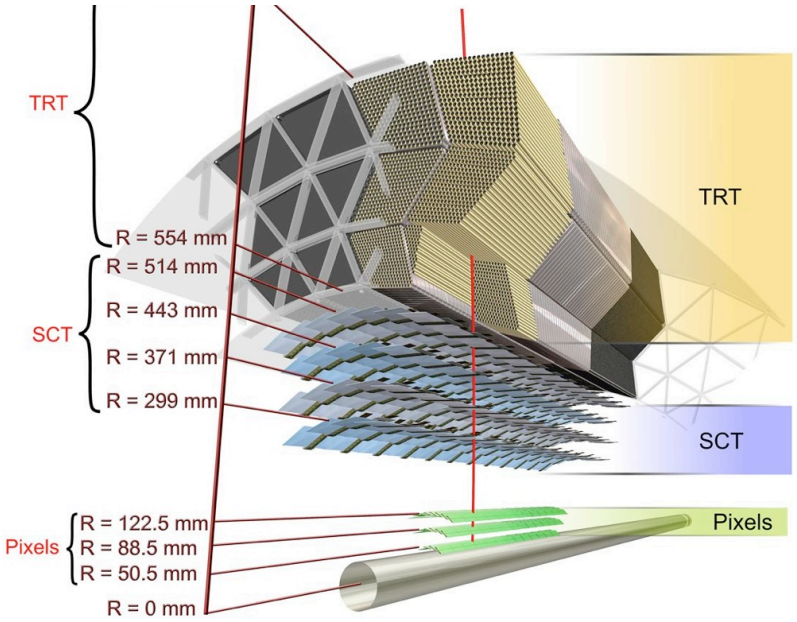
Motivations

Upgrade motivation:

- ✓ increasing occupancy in the Transition Radiation Tracker (TRT) inner layers.
  - Already 30% at L_{inst}~10^{34}
- ✓ Radiation damage to SemiConductor Tracker (SCT) above 500-700 fb^{-1}
- ✓ High SCT occupancy at L_{inst}>10^{34}

- Goals of tracker upgrade:
  - ✓ Have tracking capabilities at that meet or exceed existing tracker at L_{inst}~10^{34}
  - ✓ Track trigger at L1
  - ✓ Allow collection of up to 3000 fb^{-1} (on tape) of data with good performance.





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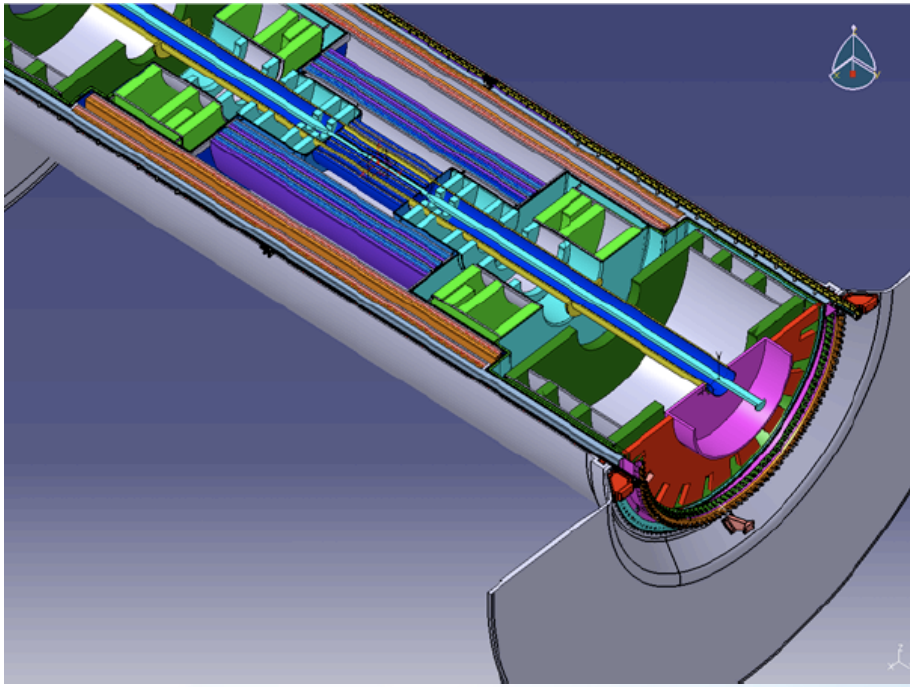

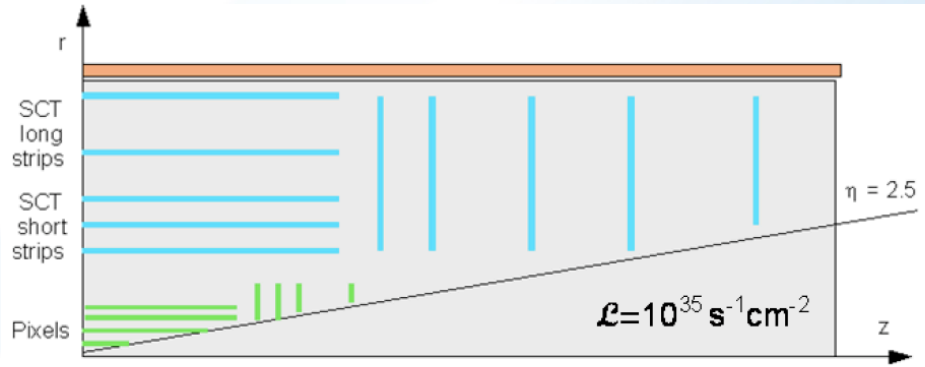

BROOKHAVEN NATIONAL LABORATORY

Motivations

Silicon IT

The replacement of the IT with a full Si-based solution is a large and complex operation

- ✓ Requires participation of new groups in addition to groups involved in existing Silicon tracker
- ✓ Large infrastructure needed at production sites

A. Cattai, ATLAS Upgrade Week, April 2010

is ~2020 realistic for Si TK?

From Phil talk :

- from sensors+ASICs in hand such to assembled arrays ~ 5y
- to commission barrel and the two FWDs together ~ 1 y

(very tight!)

Starting today → ~ 4 y for modules production/assembly

If we have ~20000 modules in new TK

→ 4 y * 250 days = 1000 days

→ 20000/1000 = 20 working modules produced and installed / day

(so far up to 15 mod/day during 1.5 y)

VERY TIGHT → better start recruiting labs now

→ conceive a more automatic industrial way to produce and test the modules

A. Cattai – PH dep

- Experience with a number of silicon detectors (P238 at SPS, E896 at AGS, STAR-SVT at RHIC, PP2PP at RHIC).
- BNL Instrumentation Division is a unique source of expertise in radiation hard silicon detectors.

BNL Role In Tracker Upgrade

Silicon IT

- Large increase in size and complexity of new all-silicon inner tracker
- Requires participation of new groups in addition to groups involved in existing silicon tracker

Stave Concept

BNL Role In Tracker Upgrade

Silicon IT

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Comparison of present and upgraded barrel strips

Current Strips (SCT)	Upgrade Strips
• 25,334 ASICs	268, 800 ASICs
• 3.2M channels	34M channels
• 2,112 hybrid circuits	16, 512 hybrid circuits
• 8,448 Silicon detectors detectors	11,328 Silicon
• 34 square meters silicon	113 square meters

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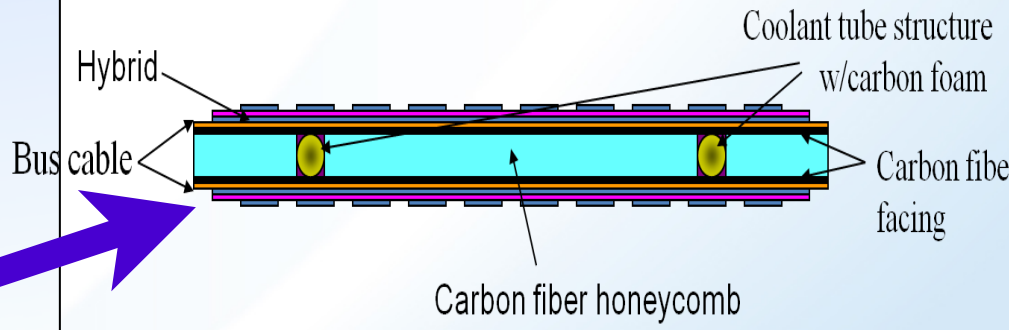
- We are heavily engaged in R&D and are actively pursuing university collaborations focU.S.ing on strips.
- U.S.-ATLAS is developing a working model with two main "centers":
  - ✓ Pixels at LBNL/SLAC + western universities
  - ✓ Strips at BNL + eastern universities
  - ✓ Collaboration LBNL/BNL for common developments



- U.S. Proposal for "stave" concept adopted as ATLAS baseline design: successful collaboration of LBNL, BNL, and U.S. universities

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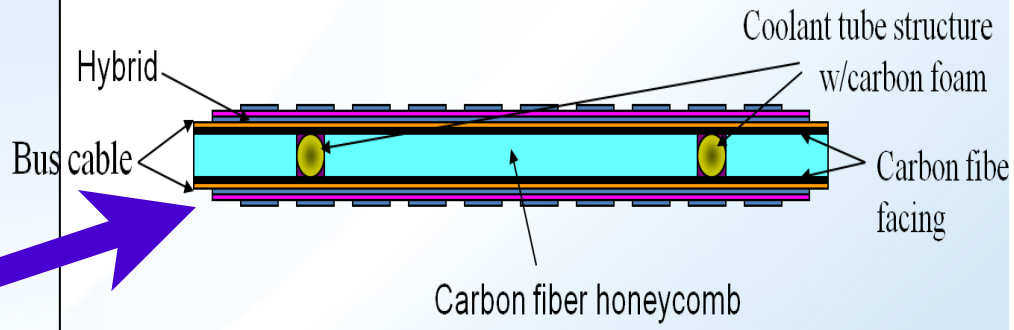

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Silicon IT

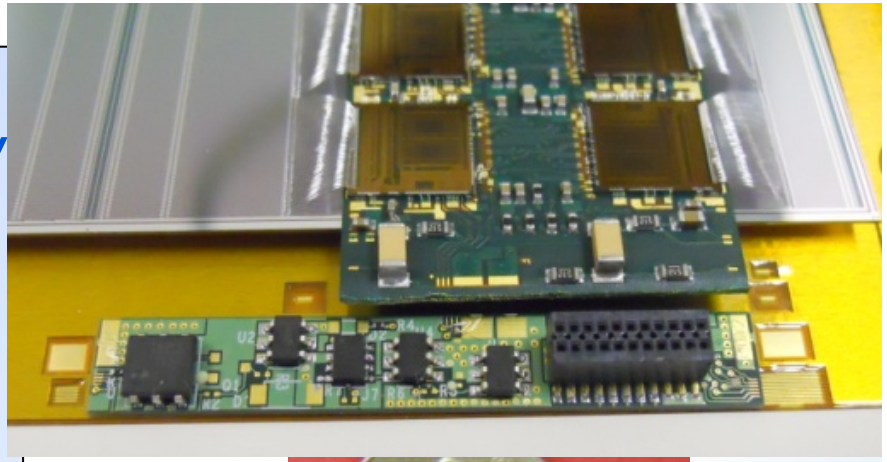
Current R&D Activities

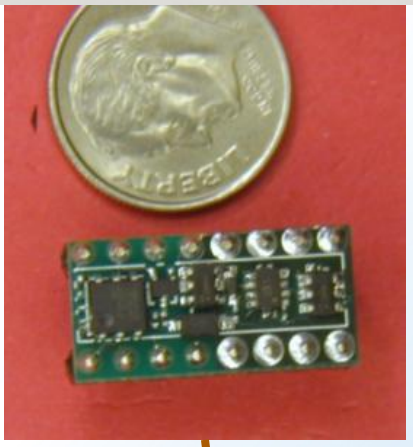
- We are leading stave prototyping efforts in U.S. (in collaboration with LBNL and Yale Univ.)
- We proposed a real and slow control protection of serially powered stave now accepted by ATLAS as baseline; will need to be incorporated in cU.S.tom ASIC
- We pioneered a new technique of testing of large sensors that is now being implemented at Stony Brook
- We have developed (with LBNL) one of the main competing designs for barrel support structures and stave support structures

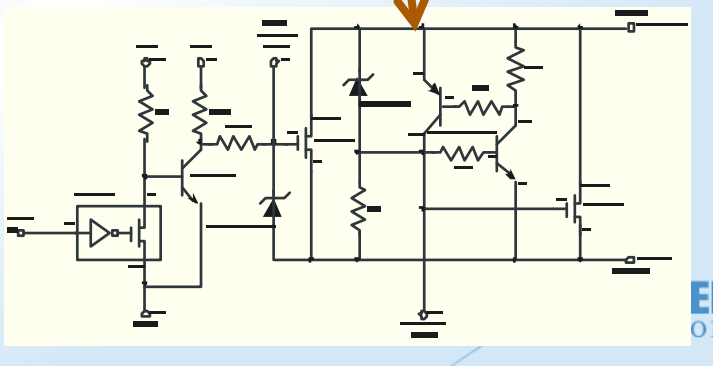
Silicon IT

Recent accomplishments

- BNL has developed protection circuitry for serial powering schemes and, in collaboration with Yale, radiation hardness studies of commercial components for DC-DC converters.
  - ✓Discrete prototype of the protection circuit for stavelets has been built and tested. It performs as predicted.
- Irradiations at BNL of commercial DC-DC converters have established:
  - ✓suitable technology up to 100 MRad
  - ✓LDMOS and GaN switches are promising technologies and are being pursued





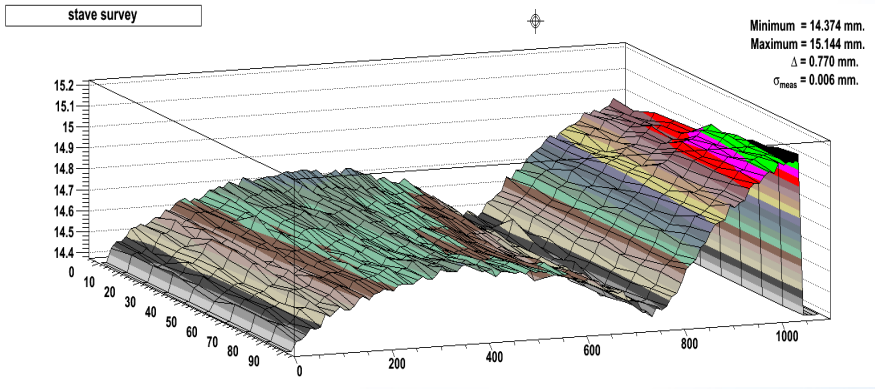


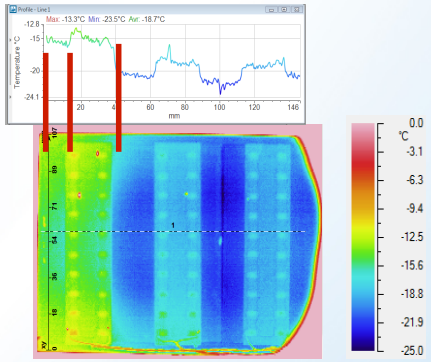
Recent accomplishments

Silicon IT

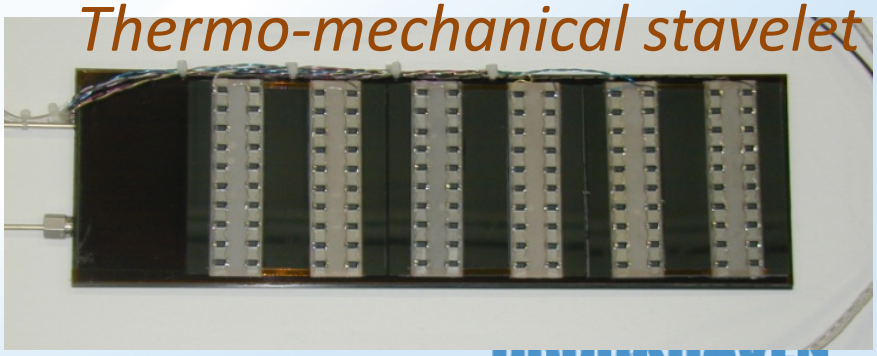
In collaboration with Yale we are developing the carbon fiber-composite stave cores.

- Selected by ATLAS as baseline choice for making the first cores to be U.S.ed with real Silicon modules and readout electronics
- In house techniques developed for study of stave core design and performance:
  - ✓ Laser measurement system to measure stave profiles with resolution less than 10μm
  - ✓ Custom built motor drive system for thermal imaging scans of long (1.5m) staves. Software development for imaging analysis.
- Construction of "stavelet" (~0.5m) to be mounted with real modules. Built and analyzed at Yale and BNL and sent to UK for module mounting.





Thermo-mechanical stavelet



Silicon IT

Near/Mid Term Goals

- Silicon upgrade will be a major task in Phase-II upgrades:
- We intend to become one of two worldwide centers for final stave integration.
  - ✓ We will design and produce the protection circuitry for serial power
  - ✓ We propose to take responsibility for the production 1/2 of the stave barrels
  - ✓ We will support the future testing of detectors
  - ✓ We will participate in irradiation of a subset of components for QA purposes
- We are proposing to participate in module production.
  - ✓ This is an area that requires extensive resources and no U.S. facility appears to be a candidate to assume a role.

Recent Pubs./Conf. (2009-2010)

LAr

- F. Lanni, "*Evolution of the LHC detectors*", invited talk at 20th Hadron Collider Physics Symposium, 16-20 November 2009, Evian, France
- H. Chen, "*ATLAS LAr Calorimeter Readout Electronics Upgrade R&D for sLHC*", XIV International Conference on Calorimetry in High Energy Physics, May 10-14 2010, Beijing, China
- S. Rescia, "*SiGe Front-End Prototype for the Upgraded ATLAS LAr Calorimeter*", 2009 IEEE Nuclear Science Symposium and Medical Imaging Conference, October 25-31 2009, Orlando, US
- S. Dhawan, "*Commercial off-the-Shelf DC-DC Converters for High Energy Physics Detectors for the sLHC Upgrade*", 2009 IEEE Nuclear Science Symposium and Medical Imaging Conference, October 25-31 2009,, Orlando, US
- H. Chen, "*R&D Studies of the ATLAS LAr Calorimeter Readout Electronics for super-LHC*", The First International Conference on Technology and Instrumentation in Particle Physics, March 12-17 2009, Tsukuba, Japan

Muon

K. Nikolopoulos, "*The ATLAS muon Microgmegas R&D project*", Int. Conf. on Gaseous Detector, Kolympari, Greece, June 12-15 2009

- T. Alexopoulos et al., "*The ATLAS muon Micromegas R&D project: towards large-size chambers for the sLHC*", J. of Instrumentation, vol. 4 (2009) P12015
- T. Alexopoulos et al., "*Development of Large Size Micromegas Detector for the Upgrade of the ATLAS Muon System*", Nucl. Instr. and Meth A(2009), doi: 10.1016/j.nima.2009.06.113

Silicon IT

S. Dhawan et al, "*Commercial Buck Converters and Custom Coil Development for the ATLAS Inner Detector Upgrade*", IEEE Trans. Nucl. Sci., vol. 57, no. 2, pp. 456-462 (2010)

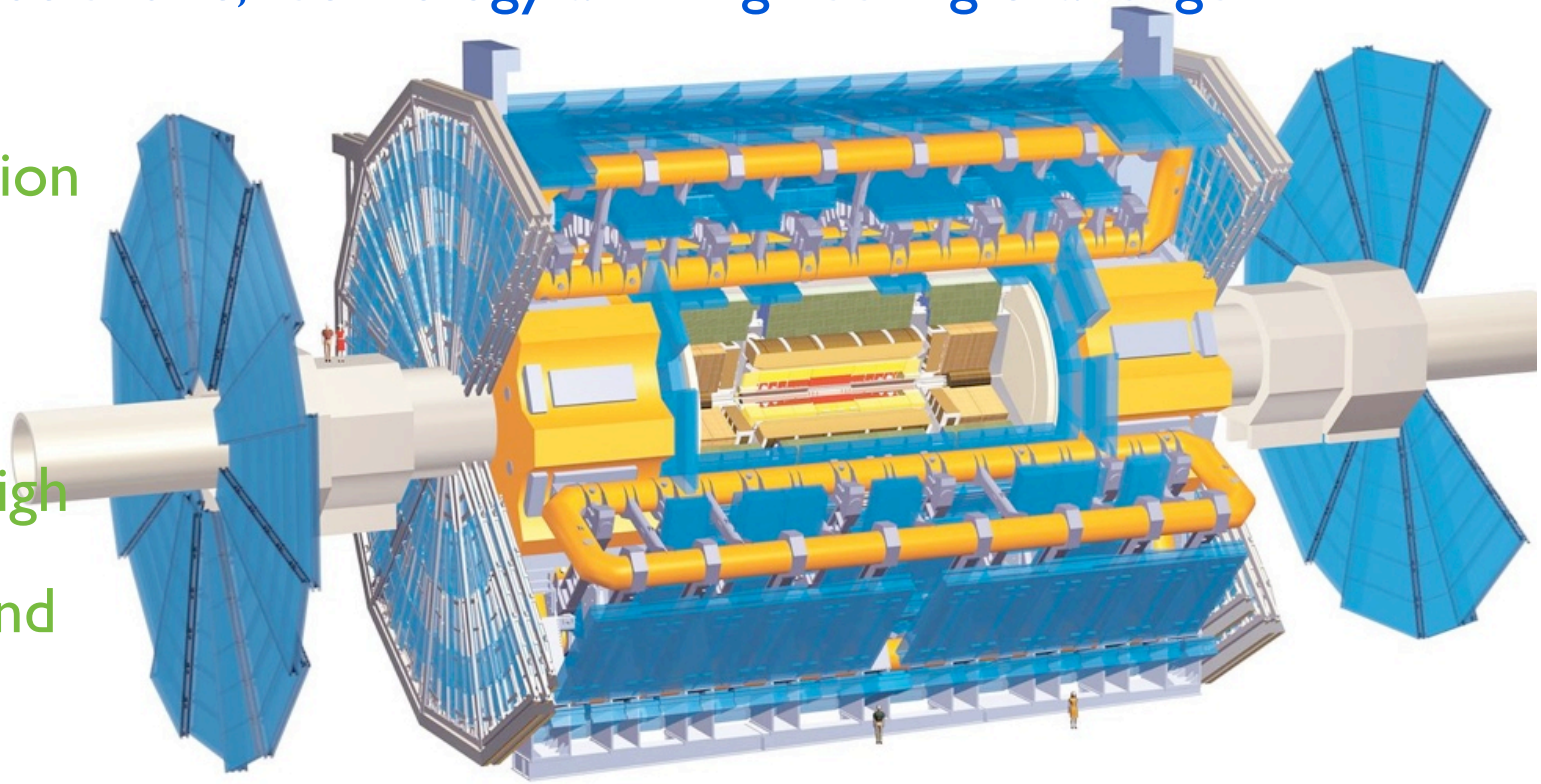
- P. Allport et al., "*Progress with the Single-sided Module Prototypes for the ATLAS Upgrade Stave*", 7th International "Hiroshima" Symposium on Development and Applications of Semiconductor Tracking Devices, Aug 29-Sep 1 2009, Hiroshima, Japan
- K. Hara et al., "*Testing of bulk radiation damage in n-in-p silicon sensors for very high radiation environments*", Nucl. Instr. and Methods A, in publication.
- J. Bohm et al., "*Evaluation of the bulk and strip characteristics of large n-in-p silicon sensors intended for a very high radiation environment*", Nucl. Instr. and Meth. A, in publication
- Y. Unno et al., "*Development of n-on-p silicon microstrip sensors for super LHC*", Nucl. Instr. and Meth. A, in publication

Additional Backup Slides: Physics Motivation and Schedule

BNL Role in ATLAS

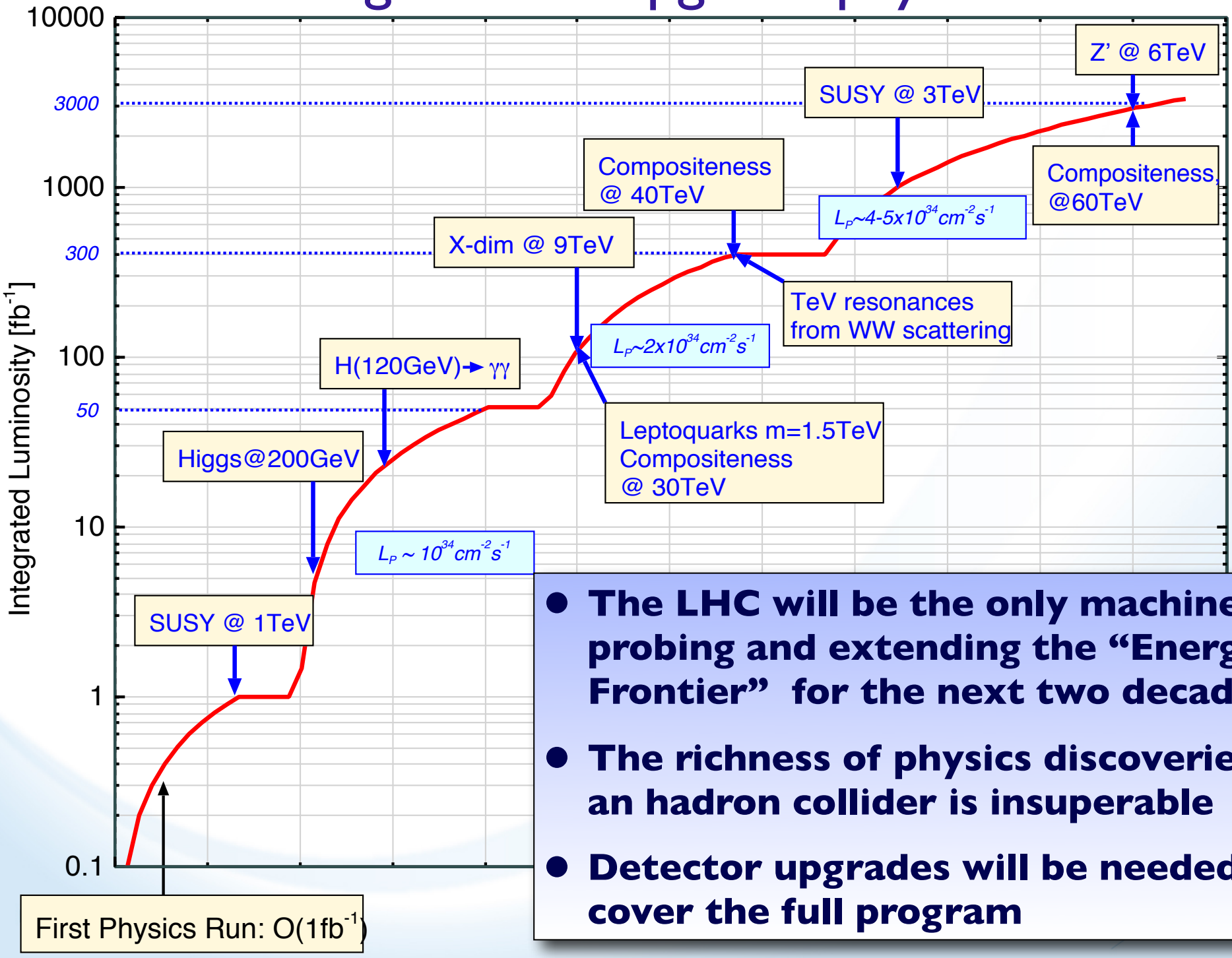
- ATLAS (and CMS) are the world's largest general purpose particle detector ever built.
- Extraordinary Scientific, Technology and Engineering challenge

- ATLAS Construction (2004-2009):
  - ✓7,000 tons
  - ✓45m long, 25m high
  - ✓3,000km signal and power cables
  - ✓1.4×10^8 readout channels



- BNL is one of the leading institutions that contributed to make the experiment ready to take data

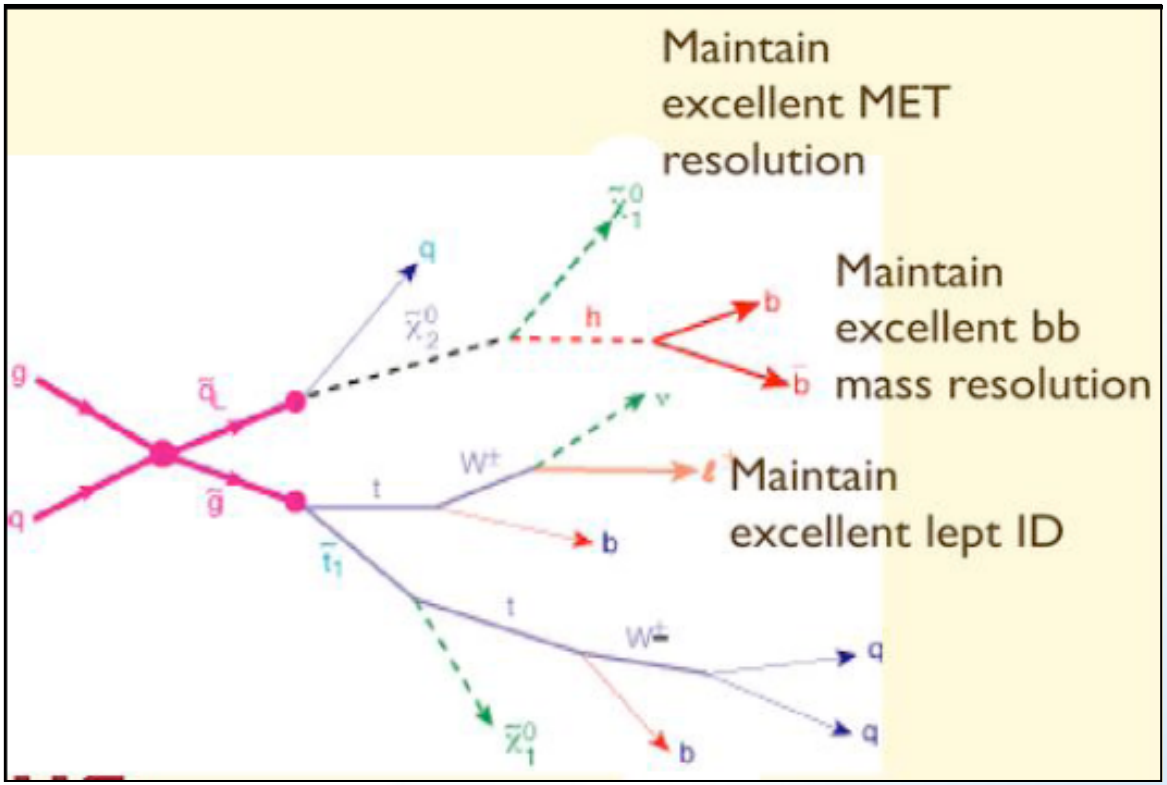
LHC ultimate goals and upgrade physics motivations



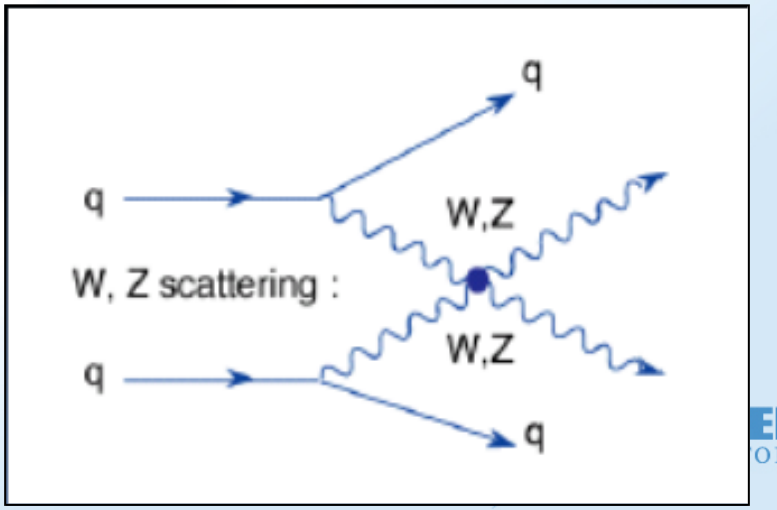
- **The LHC will be the only machine probing and extending the "Energy Frontier" for the next two decades**
- **The richness of physics discoveries at an hadron collider is insuperable**
- **Detector upgrades will be needed to cover the full program**

Why we want more integrated luminosity beyond LHC nominal design.

- Improve measurements of new phenomena seen at the LHC:
  - ✓ Higgs coupling and VB self-couplings
  - ✓ Properties of SU.S.Y particles (mass, decay BR's,...)
  - ✓ Couplings of new Z' or W' gauge bosons (e.g. L-R symmetry restoration?)
- Search low-rate phenomena inaccessible at LHC:
  - ✓ $H \rightarrow \mu^+\mu^-$, $H \rightarrow Z\gamma$
  - ✓ top quark FCNCs



- Push sensitivity to new high-mass scales:
  - ✓ new forces (Z', W_R)
  - ✓ Quark substructures



Why we want more integrated luminosity beyond LHC nominal design.

Detector Performance Requirements from Physics

- Improve measurements of new phenomena seen at the LHC:
  - ✓ Higgs coupling and VB self-couplings
  - ✓ Properties of SU.S.Y particles (mass, decay BR's,...)
  - ✓ Couplings of new Z' or W' gauge bosons (e.g. L-R symmetry restoration?)
- Search low-rate phenomena inaccessible at LHC:
  - ✓ $H \rightarrow \mu^+\mu^-$, $H \rightarrow Z\gamma$
  - ✓ top quark FCNCs

- Energies/masses in the few-100 GeV range:
- Detector performance @ sLHC needs to be maintained (or improved) despite pile-up

- Maintain p_T , MET resolution, trigger efficiencies for many channels of interests.
- Maintain vertexing capabilities BUT:
  - ✓ Higher occupancy
- Maintain electron ID and muons (for W/Z, W'/Z', Higgs and SU.S.Y)
- **Sharper trigger turn-on curves**
- Jet tagging in the forward calorimeters and central jet veto (from WW scattering - Higgs couplings or VBF)

- Push sensitivity to new high-mass scales:
  - ✓ new forces (Z', W_R)
  - ✓ Quark substructures

- Very high energies/masses (~1 TeV):
- Not very demanding on detector performance
- Slightly degraded detector performance probably acceptable

kgrounds